16 21 27 32 40 46
49
62

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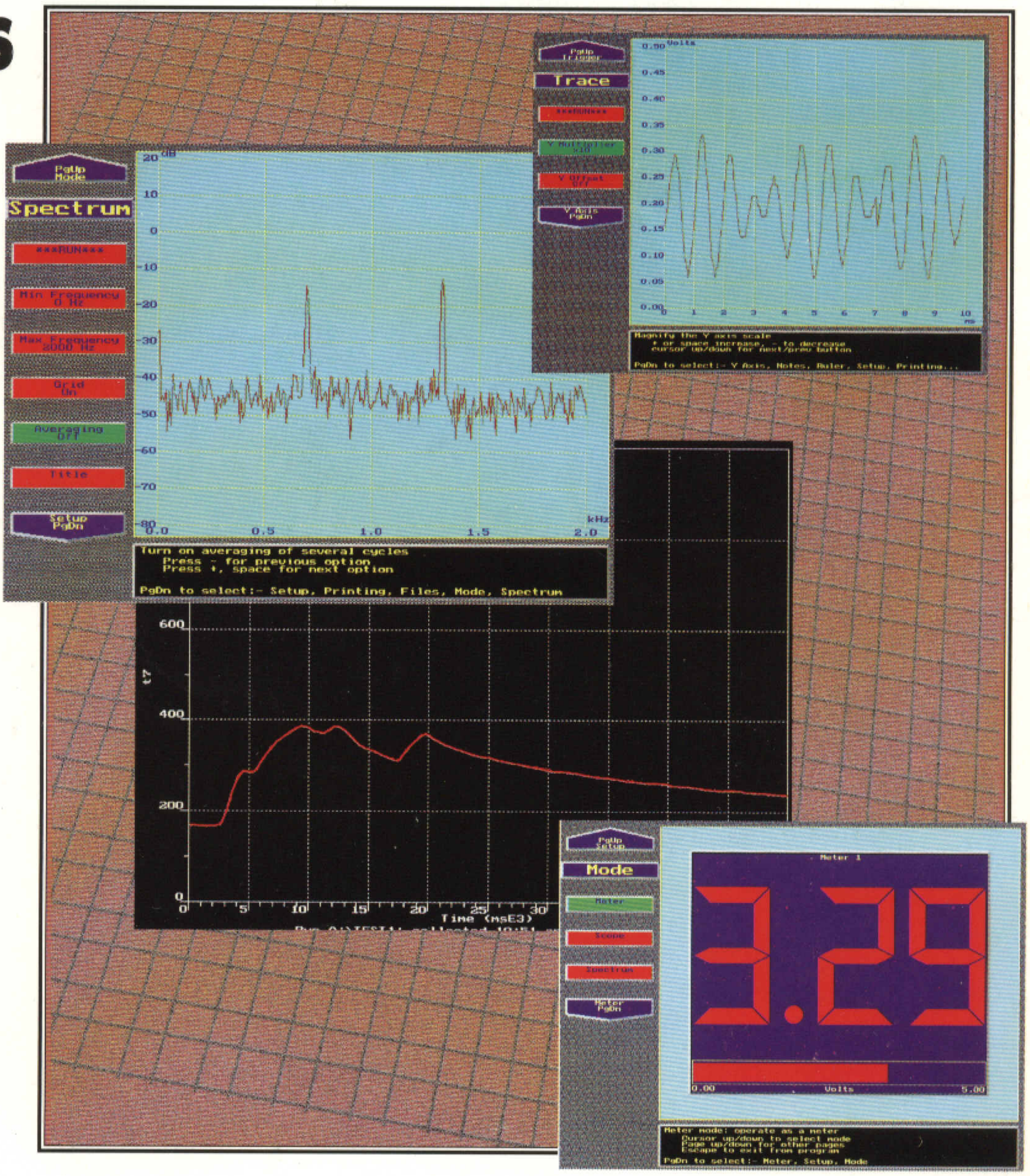
Virtual Instrumentation



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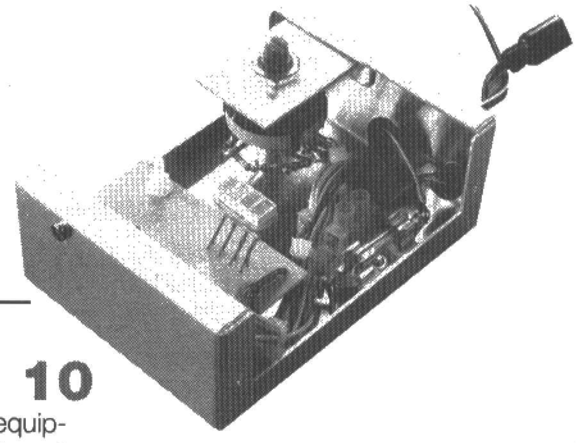
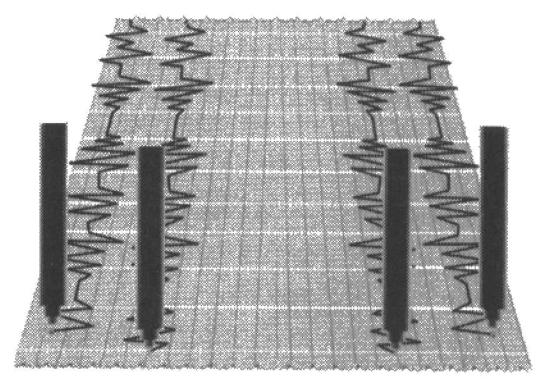
Contents

Volume 23 No.4
April 1994

Features & Projects



Project
Power supplies for electronic equipment
21

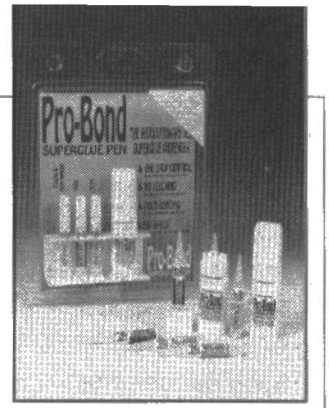


Regulars

ETI NEWS

New Pro-bond Superglue Pen

Tufloc Industrial Products has just launched a new range of Pro-bond Cyanoacrillate Superglues, specifically designed for the serious hobbyist. The leading product in the range is the totally new Superglue pen, which is capable of accurate and fast one drop dispensing, with cartridges of different grades of cyanoacrylate that can be easily inserted in the pen. This provides a very economical and clean method of applying Superglue, avoiding the blocking and short shelf life seen with more traditional tubes.



For more information contact Tufloc on 0780 65135.

Super Low Power SRAMs from Mitsubishi

Mitsubishi has introduced a third generation super low power 256kbit SRAM, including 3V and 5V operation products. The new devices feature a maximum operating current of 20mA at 3.3V and 50mA at 5.5V. Maximum stand-by power consumption is just 2µA at 3.3V (0.05µA typical) depending on the version.

For 5V operation devices, access times are 55 or 70ns and package options include both 28pin, and 0.6in DIP. All inputs and outputs are directly TTL compatible and data input and output pins are common. It is organised as a 32k x 8bit device and manufactured using triple polysilicon 0.7um CMOS. Resistive load NMOS cells and CMOS peripheral circuitry makes for higher density and low power operation, ideal for battery backed operation.

For further details contact Mitsubishi, at Hatfield, Herts., on 0707 276100.

Recycling Metals in Batteries

Using a combination of solvent extraction and ion exchange, the Batenus process recovers more than 99.5 per cent of battery and accumulator components, according to developer Piri Gmbh of Stuhlingen, Germany. The process has a closed solvent and water circulation system and operates with all battery types, except those that contain lead.

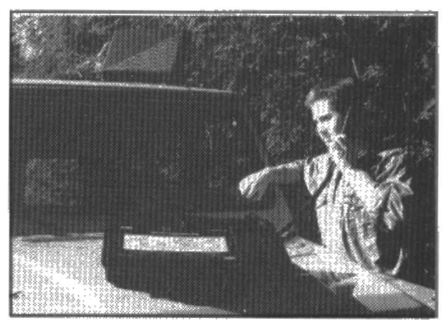
Firstly, the batteries are slit and shredded, then the paper, plastic and iron fractions are mechanically removed. The remaining battery powder is then mixed with sulphuric acid. The insoluble fraction, containing manganese dioxide and graphite, is washed, dried and recycled. Chlorine, in the form of sodium hypochlorite, is removed by contacting the acid solution with sodium hydroxide. Zinc, copper, cadmium and nickel are successively removed in solvent extraction and electrolysis steps, while iron hydroxide and manganese carbonate are recovered by solvent stripping, sedimentation (of the iron hydroxide), and drying. All solvents and water recovered via membrane separation are recycled. The recovered metals are suitable for direct reuse.

Operating costs, at $1,500/m.t., are about one third those of competing recycling processes, while capital costs, for a 7,000 m.t./yr. plant, are 50% lower. Following successful pilot testing in a 12 kg/hr plant, the company has finalised contracts for two plants, each of about 7,000 m.t./yr. capacity, to be commissioned in Austria and Germany.

Briefcase satellite telephone

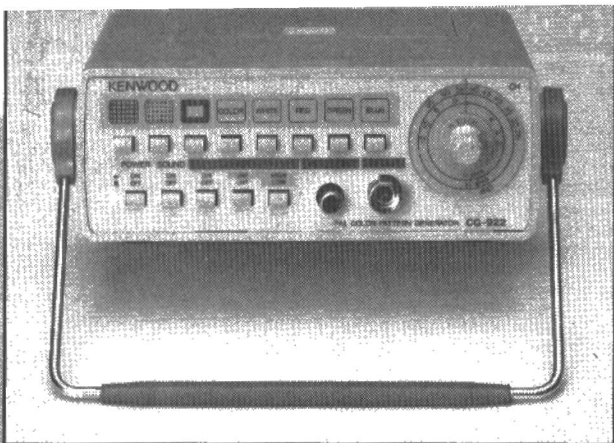
For the new Inmarsat M satellite system, the Norwegian company ABB Nera has developed the world's smallest satellite telephone for voice, fax and data communications. The Antennae and radio electronics are integrated in the detachable lid of a 9kg briefcase that can be carried by hand and be ready for worldwide communications from anywhere, in a matter of two or three minutes.

The system has been designed to operate in any conditions and in any climate, and will run on virtually any type of power source, from 10V DC to 276V AC. The unit can be linked to a PC for data communications via an RS232 Hayes compatible interface. Both computer data and digitally encoded voice or fax data are transmitted at 2400 bits/sec.



This compact satellite phone system should appeal to people who work in remote places and who need reliable communications. ABB Nera says that Inmarsat M call charges can be lower than those for international telephone calls from hotels.

For more information contact ABB Nera in Billingstad, Norway on +47-66 84 47 00.



New Portable Colour Pattern Generator

The Kenwood CG-922 is a battery portable colour pattern generator, which provides both video and RF outputs covering UHF and VHF bands, and includes a 1kHz audio signal superimposed inter-carrier. The instrument provides a standard colour bar; red, green, blue and white rasters, plus dot and cross-hatch patterns. A window pattern is also a standard feature which can be used to check video amplifier characteristics and high voltage circuit stability.

The CG922 is compact in design, measuring only 162 x 60 x 130mm, and weighs 760gm, including batteries. It comes complete with cables and batteries at a cost of £445.

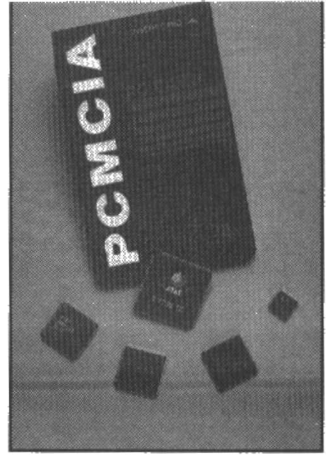
For further information, contact Trio-Kenwood UK Ltd of Watford on 0923 816444.

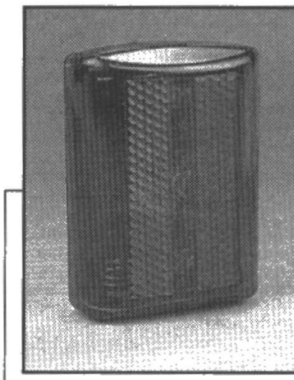
Single Chip Ethernet for PCMCIA

AT&T has just launched a single chip Ethernet which will put LAN, modem and fax communications onto a single PCMCIA card. Jointly developed, with Socket Communications, for use on its TRIO system, the chip integrates Ethernet LAN and 14.4kbits/sec fax/modem capability.

This new chip is, thanks to its low profile and power down capability, also ideally suited for any portable, light weight computer system such as laptops, notebooks and personal communications devices.

For further information contact AT&T Dataline on 0732 742999.





'Laser' Safety Light for Cyclists, Joggers, Walkers

A compact, lightweight, high intensity LED lamp designed for safety applications has been launched by Maplin Electronics. The lamp will clip onto a bicycle lamp mounting, onto a belt or a bag and draw attention to your presence in the darkness. The red, high brightness, triple-LED lamp can be switched to steady or strobe-like flashing mode. This handy little unit costs £4.95 and requires two AA size batteries.

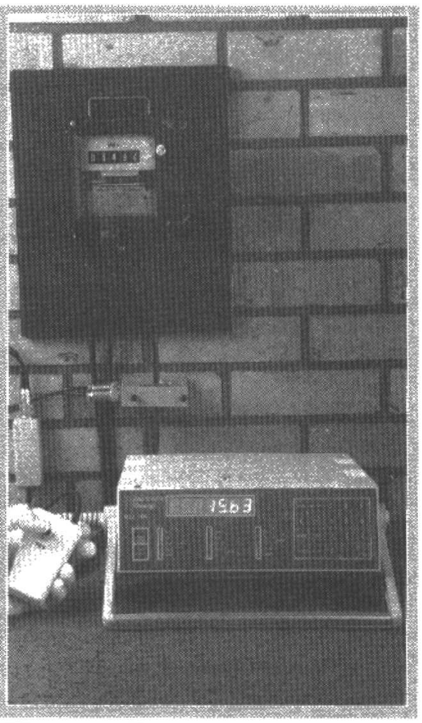
For further information contact Maplin on 0702 554161

Checking Power Usage

On 1st April 1994 we will see the introduction of the 100kW Code 5 Metering Market. This means that anyone using more than 100kW can purchase both their own electricity from a supplier of their choice and equipment from a local installer. This should create competition in the electricity supply industry but it will also make it important that meter installation can be checked and verified.

To do this, Northern Design has introduced a special test meter for checking electricity meters of both the rotating disk and pulse output type. The meter tester has an accuracy of ±0.5% and can thus check the QC of an installation, as well as resolve disputes over meter accuracy. The Northern Design meter can also give precise readings of true RMS voltage and current (either direct or via clamp-on CTs), instantaneous power, power factor, energy and frequency. All outputs can be displayed directly or output to a computer via a RS232 port.

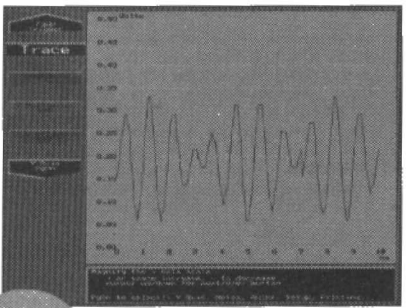
For further information, contact Northern Design, of Bradford on 0274 729533.



Advances in Batteries for Electric Vehicles

A U.S. company, Electrosource Inc. of Austin, Texas, has developed a valve regulated, lead acid battery that offers high specific energy (50 Wh/kg) with a projected life span of about 80,000 miles. The battery features high power capability (300 vs 90W/kg at 20% charge) than conventional valve regulated units. A commercial plant, to deliver 5,000 batteries a month, is now under construction.

A patented process is used to co-extrude an alloy of lead and tin into a filament of high tensile strength, making a small diameter wire that is woven into light weight mesh grids. The grids are then coated with a proprietary paste and assembled into electrical plates. Horizontal placement of the plates makes the batteries strong enough to withstand the charge/discharge cycles. Also, unlike traditional batteries that are cast on a grid, these units can be made using a continuous process, making production much easier.

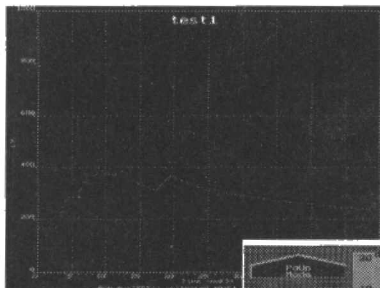


Virtual Instrumentation

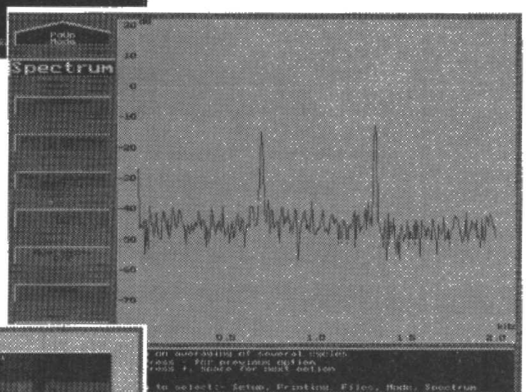
An electronics lab in your PC?

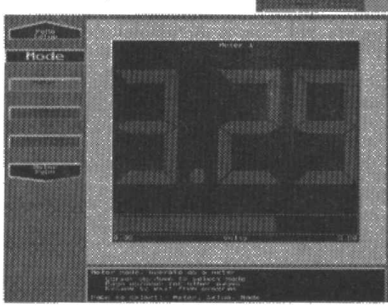
The word virtual has become very popular recently. We hear talk of 'virtual reality' systems, we are asked to use 'virtual disk drives' and now we are seeing the term 'virtual instrumentation' creeping into everyday use, among the scientific and technical community. So what does the term 'virtual' actually mean in these contexts?

In all these cases, 'virtual' is used to indicate that a computer is being used to simulate the action of something. So in virtual reality, the computer and special peripherals are used to make an individual feel as if he or she is actually living and moving within an environment, entirely simulated by the computer. Similarly, a virtual disk drive does not exist as a piece of hardware, but as a computer simulation of the disk drive hardware, although to the user the virtual disk behaves exactly like a real disk drive.



This brings us to the concept of 'virtual instrumentation', in other words using a computer, plus suitable input/output hardware, to simulate the characteristics and behaviour of a test/measurement/data logging instrument. Thus we can plug an analogue top digital converter board into a PC and, with suitable software, use it to emulate the output of a digital voltmeter, an oscilloscope, or a spectrum analyser. The outputs of these 'virtual instruments' will be displayed on the screen in a manner that exactly copies the more familiar dedicated instrument.





What is happening in a virtual instrument is simply that the function of data analysis and output is being performed by computer software rather than by special purpose hardware. The actual data acquisition is still performed by specially designed hardware. Assuming that a PC is available, this is a sensible use of resources since probably 80% of the circuitry inside a dedicated test instrument is concerned with data display and analysis, rather than with data acquisition.

Think about a common piece of test equipment, the oscilloscope. This will use amplifiers, to alter the amplitude of a trace and a variable time base generator, to control the time taken for the trace to move across the screen. Then, of course, there are all the EHT electronics for the CRT tube and amplifiers for the deflection plates, etc. Every single one of these functions could be emulated on a PC using software. Software could change the time base and the signal amplification and, of course, the PC's screen will replace that of the oscilloscope CRT and the PC's keyboard could replace the control knobs and buttons.

Data Acquisition

A virtual instrument thus consists of two components, firstly the signal conditioning and where necessary the analogue to digital conversion circuitry, secondly the software which will analyse and display the data input by the computer from this circuitry. The input circuitry is broadly classified as data acquisition hardware.

We can divide data acquisition hardware into two main categories, analogue data acquisition and digital data acquisition. By and large, digital data acquisition is confined to testing the state of simple on/off devices such as switches, the photosensors used in rotary or linear position sensors, or monitoring the output from a digital circuit. However, it might also be used to input data from a remote instrument which converts analogue data into digital form.

Analogue data acquisition, on the other hand, has a very wide range of applications, including testing analogue circuitry, inputting data from a very wide range of different sensors and digitising waveforms. There are, of course, a few types of specialist data acquisition systems which bridge the differentiation between digital and analogue, for example frequency measuring systems.

For a digital computer, digital data acquisition is simple, all that is needed is a suitable parallel I/O card. The most widely used such cards are based around the 8255 PPI chip, which provides the user with 24 programmable I/O lines. Some boards use two or more 8255 chips to give 48 plus I/O lines. It is useful to have both input and output lines available, since digital data acquisition applications often require the use of one or more output lines to produce a clock pulse or data input pattern.

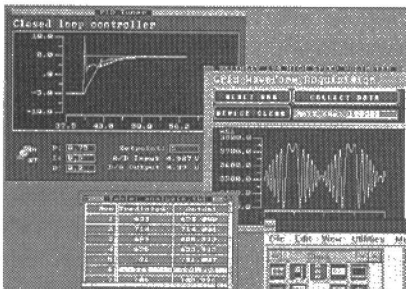
A typical example of this would be the use of a programmable I/O port to automatically test ICs or digital circuits. In such an application, a test pattern on the IC's input lines would be used to produce a specific output on the output lines. This output would then be compared against a logic table for that particular device or circuit. If it matches the table, then the circuit under test is behaving as expected and the computer can try another input test pattern. Testing a digital circuit may involve just a handful of test pattern inputs or it may involve thousands, depending on the circuit's complexity.

When dealing with logic circuitry at standard logic voltage levels there is little need for any form of signal conditioning, other than line buffering. However, signal conditioning may be necessary when dealing with inputs of higher or lower voltages and perhaps opto-isolation to protect the computer from accidental short circuits or power surges.

Analogue data acquisition hardware is based around the analogue to digital converter. The variations between systems will largely rest upon how many separate analogue inputs it can digitise, the number of channels, the precision with which it can measure the input signals and the speed at which it can input data. Some systems will also incorporate a certain amount of signal conditioning, which will allow larger or smaller voltages to be measured. For more information on these factors, see the information in Box 3.

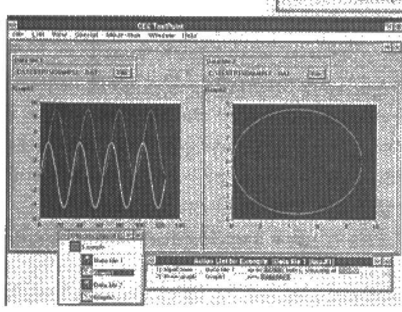
Data Generation

Not all the instrumentation used by a scientist, a technologist, or an electronics engineer involves the input and measurement of analogue or digital data. Quite often, it involves the creation of specific types of output, for example a signal generator, or a logic pulse generator. Given the correct output circuitry, these types of instrument can be just as easily emulated as those involved in data input and measurement.



By and large, the circuitry used to input logic data is the same as that used to output such data. However, that used to generate analogue signals is entirely different. This type of circuitry is built around a D/A converter and can come in single and multiple channel versions, with 8, 12 or more bits resolution and with varying output rates (where the output rate corresponds to the sampling rate on an A/C system).

The output from a D/A converter is a computer controlled voltage. Indeed, such systems can be used to create very accurate computer controlled power supplies. But their most common use is to generate specific waveforms and signals, so we could mathematically generate a perfect sine wave of varying frequencies, or we could generate a composite wave form, created by adding two or more sine waves of different frequencies. We can, in fact, use the computer to generate any waveform which is capable of being expressed mathematically and output it as a real time signal, the frequency of which is only limited by the speed of the processor and the complexity of the signal generation software.



Virtual Instrument Software

Software is of course the key to the whole concept of virtual instrumentation. The products currently on the market fall into two categories, special purpose virtual instrumentation and data acquisition packages, and general purpose instrumentation related languages.

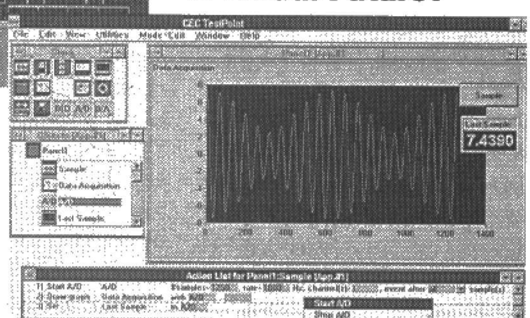
In the first of these categories we have products like Pico Technology's Picolog and Picoscope. Comprehensive virtual instrument software packages which have been designed to support a specific range of hardware products. These form an excellent introduction to the concepts of virtual instrumentation, but they lack the flexibility of more general purpose software.

Flexible virtual instrumentation software will be the trend of the future, in particular instrumentation related object oriented languages. Such languages will allow users to build their own virtual instrumentation to suit their own specific needs. Using basic hardware modules, the instrument designer will be able to use this type of object oriented language to add virtual functions, a virtual amplifier here, a virtual switch there.

Indeed, in the future he will be able to go further and integrate a number of virtual instruments, create a script to show how each one behaves at a specific time and how it relates to the others. The designer will also be able channel data into specified data manipulation packages, such as spreadsheets with graphical data output capability, and even automatically manipulate and process that data.

Such object oriented data acquisition and virtual instrumentation languages are not that far away. As this issue goes to press, Keithley Instruments has just launched what it claims is the first such package. Called TestPoint, it has been designed to free engineers and scientists from restrictive programming barriers. It runs under Windows and allows the user to create and run measurement and analysis applications for any test or research task.

A Virtual Future?



Virtual instrumentation is still a very new concept, but it is one which has enormous potential for both the professional and the amateur in all areas of science and technology. The most important thing is its flexibility and versatility. A single analogue to digital converter card can, by simply changing the software, become a digital voltmeter, an oscilloscope, or a spectrum analyser. One can add new features and new functions simply by changing the software.

For the amateur and those on low budgets, virtual instrumentation looks set to change the economic basis of the instrumentation market. In the past, instruments were expensive because they were produced and sold in small quantities to highly specialised markets, but the hardware for virtual instrumentation systems can be mass produced. It will be the same basic data acquisition hardware used in an oscilloscope as that used in a spectroscope, or a gas chromatograph. The data acquisition hardware will be mass produced and, therefore, cheap.

The software will also be mass produced thanks to virtual instrument related object oriented languages, which will allow any type of virtual instrument to be quickly and easily built in software. With this type of software, end users will be able to create virtual instruments which exactly suit their specific needs.

The components that will still need to be specially made, and

A few applications for virtual instrumentation

Oscilloscope, both ordinary, multiple trace and storage
Digital voltmeter and transducer input
Spectrum analyser
Chart recorder
Logic analyser and logic pulse generator
Frequency meter
Waveform generator
Automatic component and circuit testing

therefore will remain expensive, will be the sensors and signal conditioning components. But these are a relatively small part of current instrumentation costs, so we can expect to see the overall cost of instrumentation drop considerably whilst the range of available instrumentation will expand considerably.

All this must be good news for end users and a considerable challenge to instrument manufacturers. Lower prices will mean a larger market potential! After all, you may not have been able afford that oscilloscope but you may well be able to afford a whole range of virtual instruments to put inside your PC.

Some examples of virtual instrumentation applications

To see how virtual instrumentation could be used to cost effectively replace dedicated instrumentation, we looked at a couple of example applications.

The first application involved a study of the heat distribution in a house, in order to determine where insulation would best be applied, where extra radiators might be required and where savings could be made by making use of warmth from sunlight, etc., thus reducing the required heat output from local radiators. In order to make such decisions, the temperature of each room, as well as the outside temperature, needed to be measured at all times of day over a long period, through different seasons, different types of weather and different levels of house occupancy and usage.

The collection of such an enormous quantity of data could obviously not be done by hand and electronic temperature measurement techniques were the solution. Traditionally, this would have involved connecting a number of temperature sensors to a multi-channel chart recorder and then manually extracting any relevant information from the paper charts. However, by using the concept of virtual instrumentation, we could replace the chart recorder with a computer and then use the computer to help us extract the necessary information. A technique which is faster, more reliable and less time consuming.

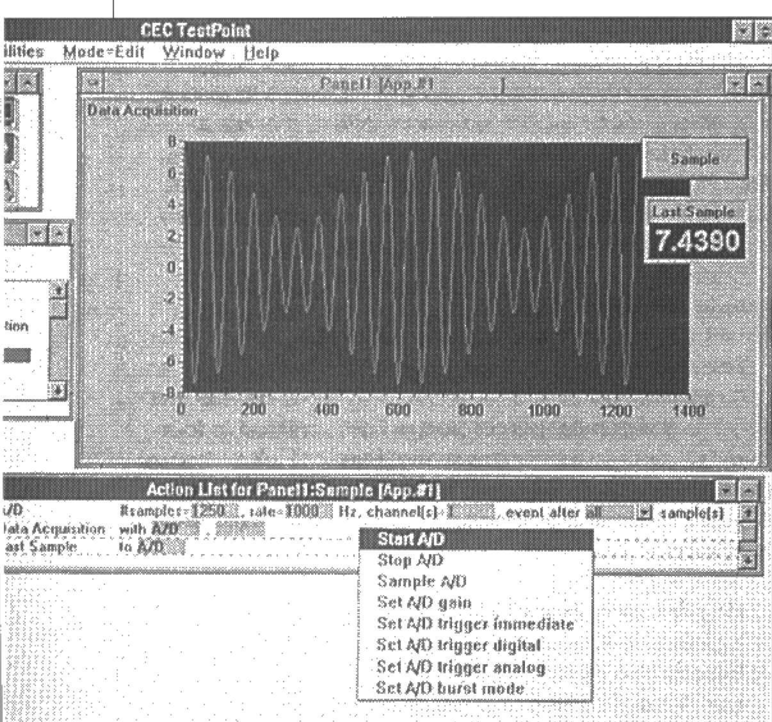
The temperature was to be measured in five rooms, two hallways and outside, so 8 channels of input were needed. The sensors were simple LM35 temperature sensor ICs, connected to the data acquisition unit by light gauge coaxial cable. The data acquisition system used in this application was an ADC16 8 channel ADC from Pico Technology. It is a low cost, simple data acquisition unit, with an 8 to 16 bit resolution and a 6.6ms conversion time. For measuring temperature, 8 bit resolution was more than adequate and sampling rate was limited to one per hour.

The whole system, the eight temperature sensors and the ADC16, were connected to a PC running a virtual instrument chart recorder program from Pico Technology, called Picolog. With this software, the data could be input at regular intervals from all eight channels, with each channel being calibrated to convert voltage into degrees Centigrade (calibration was at the start of the data acquisition process and involved using a known reference temperature). Picolog also allowed the data to be output in graphical form.

In the second application, a clutch of virtual instruments were used to test the behaviour of a number of digital and analogue circuits. The instruments available consisted of a virtual scope, a DVM, a spectrum analyser, and a frequency meter, all provided as part of Pico Technology's Picoscope software package. The data acquisition hardware consisted of a Pico Technology ADC100. This unit plugs into the PC's parallel port and offers 12 bit resolution and a 125kHz sampling rate on a standard 386 processor.

With a standard scope lead attached to the ADC100's BNC output connector, it was possible to directly check voltages, using the DVM function, in those circuits where power was limited to +5V. Similarly the signals available at any point could be displayed on the virtual scope, or analysed using the spectrum analysis feature. Low amplitude signals could be amplified and the time base varied to display the best trace.

The above applications used virtual instrumentation products from Pico Technology Ltd. of Cambridge. We would like to thank them for their help and assistance in writing this article.



Some points to remember when using and choosing virtual instruments

Resolution

The input resolution of an analogue data acquisition board is usually specified in 'bits'. The majority of systems are either 8 bit or 12 bit. The resolution can be described by the following equation:

RESOLUTION = ONE PART IN 2 ^(#of bits)

Thus, to determine the resolution in volts, we simply take the total input range and divide it by resolution or bits. If we take a 12 bit resolution system measuring voltages in the range 0 to +5V then the overall resolution is:

Resolution = 1 part in 2^12 or 4096
Resolution = 5V FS / 4096
Resolution = .00122V or 1.22mV

It should be noted that this level of resolution is more than adequate for most applications, particularly given the fact that most transducers and sensors are only accurate to ±1%.

Sampling Rate

On digital systems, the sampling rate is determined purely by the processor's speed and the efficiency of the sampling software. However, although processor speed affects most analogue data acquisition systems, the maximum sampling rate is usually determined by the A/D conversion hardware employed. Some simple systems employ a D/A converter to generate a computer controlled ramped up voltage, which is compared with the test voltage using a voltage comparator. Even with optimised successive approximation techniques, the maximum sampling rate for an 8 bit resolution system is unlikely to be much better than about 1% of the processor clock rate. Most of the commonly available analogue data acquisition boards therefore have sampling rates between 40 and 150kHz.

High sampling rates can really only be achieved by using a type of A/D converter known as a parallel or flash converter. With such a technique, it is possible for the conversion hardware to perform sampling rates of 10 or even 20MHz. Such techniques also benefit from the fact that the processor does not have to generate a voltage ramp. They just need to read the data and store it, thereby reducing software related delays. This is the type of technique used in sophisticated virtual oscilloscope systems such as Keithley's PCIP-SCOPE, which features a 20MHz sampling rate.

With any sampling system it must be remembered that information theory dictates that you must sample at least twice as fast as the highest frequency component in your input signal, so a 20MHz rate implies a 10MHz maximum input signal frequency. If signals are present at above half the sampling rate, then aliasing can cause a problem. This means that you will see a slowly moving input signal that is actually a very high frequency signal (note that this effect is seen in movies, when a helicopter's blades appear to move slowly backwards). In such situations, an anti-aliasing filter is recommended.

Another factor to remember is that in multi-channel systems, the sampling rate on any one channel depends upon the number of channels currently open. This is because a number of channels are made available by multiplexing the separate channel inputs into the single A/D converter. So if the system has a sampling rate of 100kHz with one channel, it will only have a sampling rate of 50kHz on each channel with two channels open.

High sampling speeds can use up a lot of processor memory very quickly, so systems which use high speed sampling tend to be operated in short bursts, rather than continuously. So, a virtual oscilloscope will take short samples, using some trigger.

A short list of data acquisition hardware and virtual instrument software suppliers

Alfred Enterprises Ltd.,
Cummeen, Adare,
Limerick, Ireland.
Tel: +353 61 396 696

Comprehensive range of low cost internal slot mounted data acquisition boards for the PC. Examples from the range are: a single channel 12 bit ADC at £49, a 24 line 8255 based digital I/O board at £27.

A&G Electronics Ltd.,
513A Channelsea Business Centre, Canning Road,
Abbey Lane, London E15 3ND.
Tel: 081 519 0373

Comprehensive range of low cost internal slot mounted data acquisition boards for the PC. Examples from the range are: a single channel 12 bit ADC at £49, a 24 line 8255 based digital I/O board at £27.

Instrutek (UK) Ltd.,
28 Stephenson Road Industrial Estate,
St Ives, Cambs. PE17 4WJ.
Tel: 0480 460028

A range of PC based data acquisition products such as the £99 Handyprobe, which connects to printer port and, under software control, can measure voltages in the range 0.5 to 400V. The software will allow it to act as a digital storage scope (8 bit resolution), spectrum analyser and transient recorder.

Keithley Instruments Ltd.,
The Minster, 58 Portman Rd.,
Reading, Berkshire. RG3 1EA.
Tel: 0734 575666

This is one of the largest companies in the business and produces a very comprehensive range of professional analogue and digital data acquisition boards, that will plug into the internal slots on a PC. The company also produces a wide range of data acquisition and virtual instrumentation software. A typical product is the DAS-1200 ADC board, featuring 16 channel, 12 bit resolution, 100k sample per second, software selectable gain(10mV to 5V), plus 32 lines of digital I/O, cost £375.

Kyle Data Services Ltd.,
141 St James Rd., Glasgow. G4 0LT.
Tel: 041 552 6405.

A range of low cost data acquisition products that will plug into the parallel printer port of a PC, with up to four modules connected in parallel. Includes a 12 bit 8 channel analogue input module, an 8 channel logic input module and an 8 channel logic power drive module. Prices range from £40 to £120.

Maplin Electronics Ltd.,
P.O Box 3, Rayleigh,
Essex. SS6 8LR.
Tel: 0702 554161.

Audio Millivolt Meter

Robert Penfold shows how to accurately measure small audio frequency voltages

Accurately measuring small audio frequency voltages is virtually essential when designing, building, or servicing audio equipment. Unfortunately, most multimeters are not very good for this type of measurement. Analogue multimeters mostly have adequate bandwidths for audio frequency measurements, but the most sensitive ac voltage range usually has a full scale value of around 2 to 10V. This is of little use when trying to measure a signal with an amplitude of a few millivolts r.m.s. Digital multimeters often have adequate resolution for measuring small ac voltages, but will not necessarily have good accuracy at potentials as low as a few millivolts. Also, many digital multimeters have very restricted bandwidths. There are some exceptions, but most only offer good accuracy over a frequency range of only about 50Hz to 500Hz, which is obviously far less than the full 20Hz to 20kHz audio range. It is totally inadequate for most audio frequency testing.

Most oscilloscopes are sufficiently sensitive to handle small ac voltage measurements, but are not particularly convenient to use as measuring devices. A proper ac millivolt meter is probably the best type of instrument for audio testing and a unit of this type does not have to be particularly complex. The audio millivolt meter project featured here is an analogue type, based on a couple of low cost operational amplifiers. An analogue instrument using a low cost meter does not offer the sort of accuracy possible using a digital instrument having a 3 1/2 or 4 1/2 digit display. In fact, a low cost panel meter offers a resolution that is only equivalent to a 2 or 2 1/2 digit display. Nevertheless, the accuracy is good enough for most purposes. Also, for an application of this type, there is a lot to be said for the rapid response of an analogue display and the ease with which variations in the input level can be followed. Due to their sampling method of operation, digital voltmeters tend to become random number generators when fed with varying input levels.

This unit has four ranges which provide full scale values of 1mV, 10mV, 100mV and 1V r.m.s. The frequency response is flat over the 20Hz to 20kHz audio range. In fact, the response is flat at frequencies of up to about 70 to 80kHz, so the unit is therefore suitable for frequency response measurement, gain testing, checking the output level from microphones, etc. The circuit is powered from two 6 or 9V batteries. A precision full wave rectifier provides the unit with good linearity over the full audio range.

Precision Rectifier

On the face of it, an audio millivolt meter could consist of little more than an amplifier driving a moving coil meter via a basic rectifier circuit. Such an arrangement is fine in theory, but will not give good results in practice, due to the non-linearity of 'real world' diodes. A linear diode has a forward resistance which remains constant regardless of the applied voltage. Semiconductor diodes have a forward resistance which varies considerably with changes in the applied voltage. Ordinary silicon diodes are amongst the worst in this respect. They provide an extremely high forward resistance at voltages of up to about 0.5V. Raising the forward voltage above 0.5V results in the forward resistance rapidly falling to a very low level.

Most other types of semiconductor diode have forward resistance characteristics which are not as bad as this and germanium diodes have much better linearity. However, their forward resistance still varies significantly with changes in the applied voltage and they have inadequate linearity for the present application.

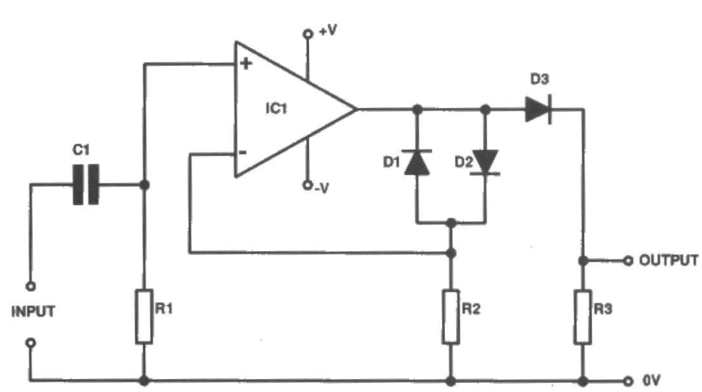


Figure 1. Basic precision half wave rectifier

The normal method of combating the non-linearity of a semiconductor diode is to use it in the negative feedback circuit of an amplifier. The circuit of Figure 1 is for a very basic half wave precision rectifier which uses this feedback technique to obtain good linearity. In this case there are two diodes, D1 in the negative feedback circuit and D2 in the signal path at the output of the circuit. The basic idea is for D1 to distort the output signal in a way that compensates for the non-linearity through D2.

The circuit is based on an operational amplifier which is used in a form of non-inverting mode circuit. R1 biases the non-inverting input of IC1 to the 0V earth rail and C1 simply provides dc blocking at the input. On positive going input signals, the negative feedback circuit consists of D2 and R2. With small output voltages, the resistance through D2 is very high in relation to the value of R2, giving a high closed loop voltage gain. With output voltages of more than about +0.5V the resistance of D2 is quite low. This gives a low closed loop voltage gain, which is likely to be little more than unity.

At the beginning of each input half cycle the very high voltage gain of the circuit results in the output almost instantly jumping to about +0.5V or so. The gain then falls back to about unity and the output voltage rises and falls in sympathy with the input level. When the output voltage falls back to about +0.5V, the resistance through D2 increases again, giving increased closed loop voltage gain. This holds the output at about 0.5V until the input voltage drops right back to zero. The output then falls almost instantly to 0V. On negative half cycles, the circuit operates in much the same way, but the negative feedback network consists of D1 and R2.

A sine wave input signal (Figure 2(a)) therefore produces an output waveform from IC1 of the type shown in Figure 2(b). This is quite heavily distorted, with positive and negative output voltages being boosted by about 0.5V or so. The output from the circuit as a whole is half wave rectified by D3, which provides a forward voltage drop of about 0.5V. In a practical circuit, D1 and D3 are diodes of the same type and R2 has the same value as R3. The voltage drop through D3 should then be accurately balanced by the boosted output from IC1, giving a precision half wave rectified output signal (Figure 2(c)). A small amount of additional circuitry is all that is needed to provide full wave rectification. It is basically just a matter of inverting the negative going signal and mixing them with the positive half cycles.

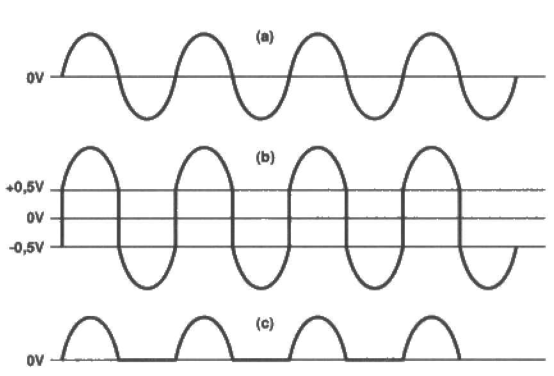


Figure 2. (a) Sinewave input signal.
(b) Output from amplifier.
(c) Final rectified output signal.

Circuit Operation

The full circuit diagram for the audio millivolt meter is provided in Figure 3. S1 plus R1 to R5 form a four step attenuator at the input of the circuit. The basic sensitivity of the circuit is 1mV r.m.s., but the attenuator can be used to reduce the sensitivity, giving the additional 10mV, 100mV, and 1V ranges. The attenuator also provides biasing at the non-inverting input of IC1 and sets the input impedance at a suitably high figure of just over 100k. IC1 merely operates as a pre-amplifier stage which has a voltage gain of about 55 times. R7 and R8 are the negative feedback network for IC1.

The precision rectifier is a full-wave type which is based on IC2. At first sight this looks very much like an ordinary non-inverting amplifier, which drives a moving coil meter via a bridge rectifier (D1 to D4). Closer examination of the circuit shows that the meter and rectifier circuit are included in the negative feedback circuit. As a result, the output signal of IC2 is distorted in the desired fashion, compensating for the non-linearity of the diodes in

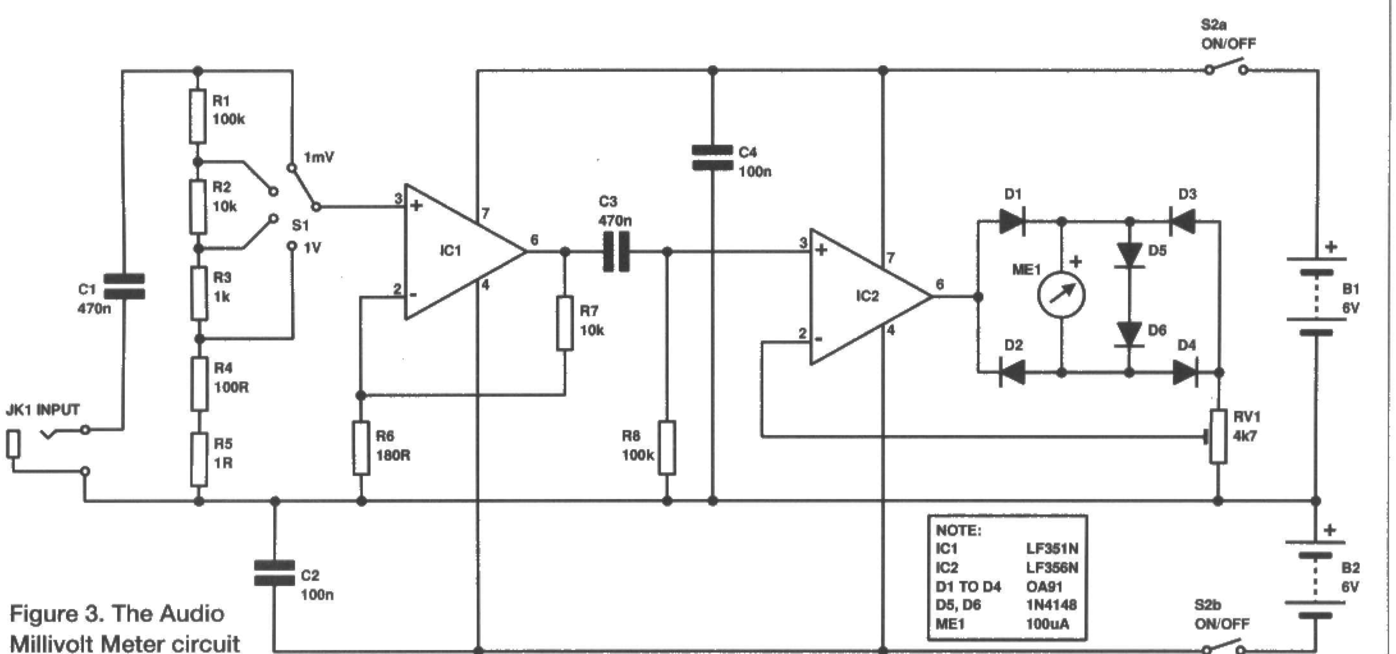
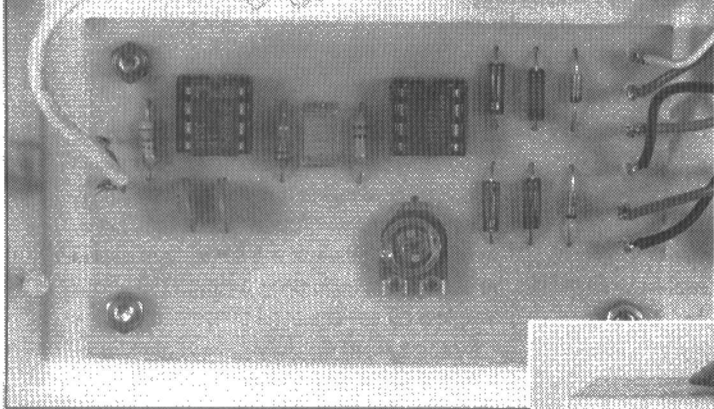
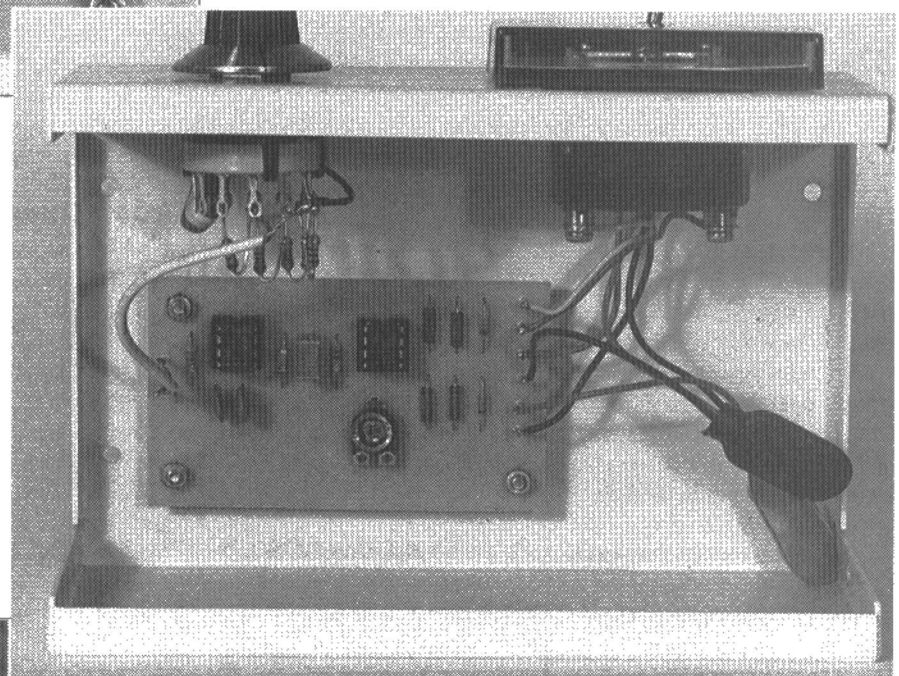


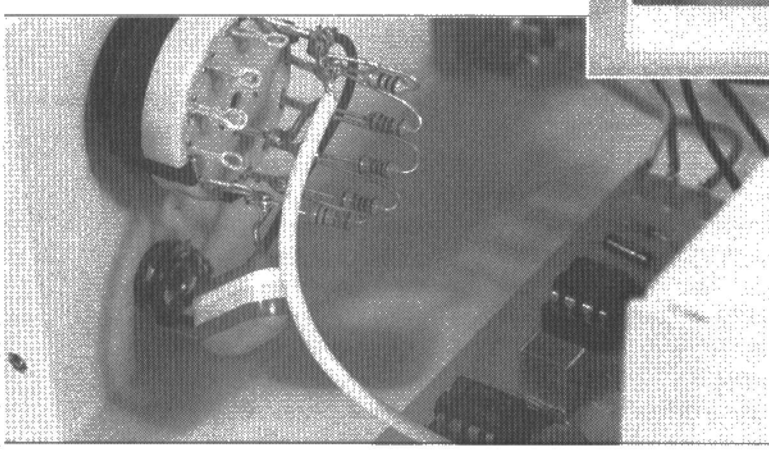
Figure 3. The Audio Millivolt Meter circuit





the bridge rectifier. This enormous simplification is possible because the meter does not need to have one terminal connected to earth.

Germanium diodes are used in the bridge rectifier because they have much lower forward voltage drops than silicon types. This does not have much effect on performance at low frequencies where the amount of negative feedback is so high that it is well able to compensate for extreme non-linearity through the diodes. It does give significantly better performance at high frequencies though, where the closed loop gain of IC1 is not much less



than its open loop gain. The amount of negative feedback is governed by VR1, which therefore controls the closed loop voltage gain of IC2 as well. VR1 enables the unit to be set for the correct full scale sensitivities. D5 and D6 act as a sort of low voltage zener diode and they protect the meter against severe overloads.

The circuit requires a dual balanced 6 or 9V supply. I used two 6V batteries for the prototype, with each battery consisting four HP7 size cells in a plastic holder. The current consumption is only a few milliamps from each supply, so a couple of standard PP3 size batteries will do just as well. A mains power supply unit could be used, but is likely to be problematic with a sensitive instrument such as this. Apart from the usual 'hum' problems, there is a fair amount of high frequency noise on many mains supplies these days. Keeping this away from the input of the millivolt meter could be difficult. Unless you are prepared to go to some lengths to keep mains-borne noise away from the millivolt meter circuit, battery operation is a much better option.

Construction

Refer to Figure 4 for the printed circuit overlay. IC1 and IC2 are not static-sensitive devices, but it is still advisable to use holders for both components. C3 must be a miniature printed circuit mounting type, having 7.5mm (0.3in) lead spacing if it is to fit into the layout properly. Similarly, VR1 must be a miniature horizontal preset. Calibration would probably be much easier using a multi-turn trimpot for VR1, but accurate adjustment is possible using an inexpensive miniature preset.

Note that D1 to D4 are germanium diodes and that germanium semiconductors are less tolerant of heat than the more familiar silicon variety. It should not be necessary to use a heat-shunt when fitting these diodes, but the soldered joints should be completed fairly swiftly. It is probably best to fit these four components last of all. Fit single-sided pins to the board at the points where connections to the off-board components will be made.

For this type of project it is best to use a case of all-metal construction. When earthed to the 0V supply rail this will provide good screening against electrical noise. Any medium sized instrument case should accommodate everything, provided the case has sufficient height to take the meter. Ideally the layout of the unit should be such that there is plenty of space between the wiring at the input of the circuit and ME1 and the output wiring. If the unit is to be housed in a reasonably small case, it is not possible to have the two sets of wiring really well spaced out, but endeavour to keep the input and output wiring as well separated as possible. The input and output of the circuit are in-phase, so a careless layout is almost certain to result in instability on the most sensitive range.

Fitting the meter is likely to be a little awkward as it requires quite a large main cut-out. A 38mm (1.5in) diameter hole is needed for a normal 60 by 46mm panel meter. This can be made using a chassis punch, or a tank cutter is good for this type of thing. Alternatively, use a coping saw, 'Abrafile', or a similar tool. Once the main cut-out has been made, use the meter as a sort of template to locate the positions of the four small mounting holes. The latter should have a diameter of about 3mm.

Details of the point-to-point wiring are provided in Figure 5 (which should be used in conjunction with Figure 4). Several of the components are mounted on S1, rather than the circuit board. This makes construction of the unit slightly more difficult, but it minimises the amount of input wiring. It also minimises the stray capacitance in the circuitry around S1, which helps to

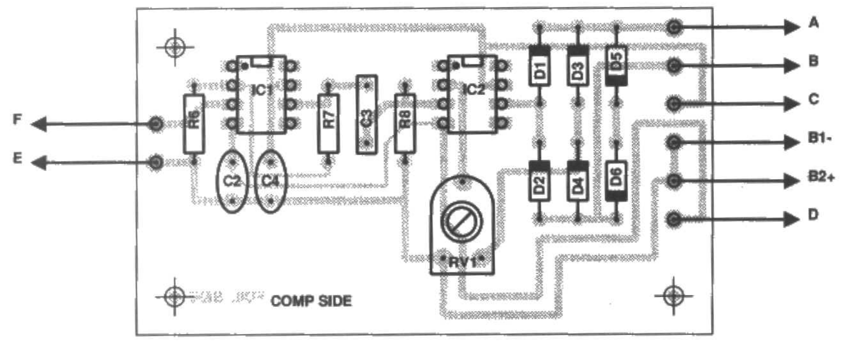


Figure 4. The PCB overlay

Start with VR1 at a roughly central setting. With the unit switched on, the meter should read zero, or something close to zero. Set S1 to the 1V position, feed a fairly strong audio input signal into JK1 and check that the meter responds to the signal. Try audio input signals at a variety of levels and check that S1 enables the sensitivity of the unit to be altered appropriately.

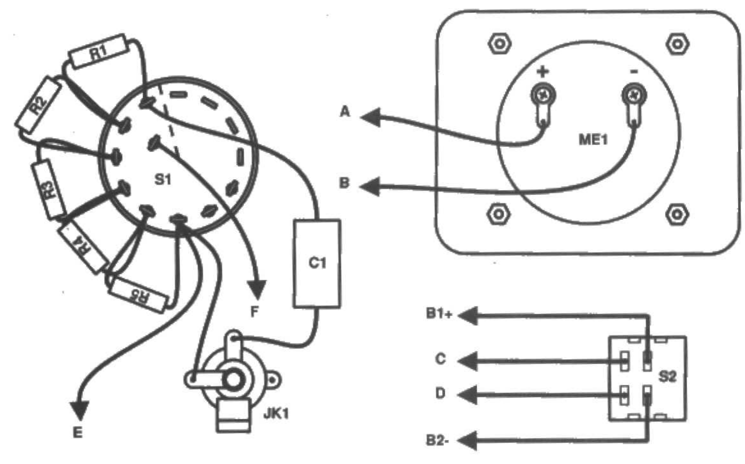


Figure 5. Details of the point to point wiring

avoid stray pick up and instability. The reduced stray capacitance maintains good accuracy through the attenuator at high frequencies.

Probably the best way to deal with C1 and the five attenuator resistors is to fit them to S1, before the latter is finally installed in the case. In order to give good accuracy on all ranges, the attenuator resistors (R1 to R5) should have a tolerance of 1% or better. Be careful not to seriously overheat these resistors when fitting them to S1, as this could alter their values significantly. S1 is a standard 1 pole 12 way rotary switch having an adjustable end-stop. In this case the latter is obviously set for 4 way operation. In this application, a make before break switch is preferable to a break before make type. The former gives less of a 'twitch' from the meter each time S1 is switched from one range to another. Two of the unused tags of S1 are used as anchor points for the attenuator resistors.

Complete the unit by adding the small amount of hard wiring. Use a screened lead to connect S1 to the printed circuit board. If you opt for 6V battery packs, the plastic battery holders are fitted with standard PP3 type battery connectors.

The 0 to 100 scale of the meter is only appropriate to the 100mV range, but it is clearly not too difficult to convert scale readings into their equivalent in millivolts on the other three ranges. It is just a matter of mentally shifting the decimal point. Additional scale numbering could be added to the meter, but there is little space for extra numbers on the scale plate and it is probably not worth the effort.

Calibration

The millivolt meter is a sensitive instrument and, as such, it needs to be used with screened test leads. Low cost test leads of the type sold for use with oscilloscopes are ideal, but a home-made equivalent can be made up at even lower cost.

If all is well, the unit is ready for calibration against an audio signal of known amplitude. It is probably best to calibrate the unit on the 1V range and at full scale. Any noise should then be swamped by the high input level. Some audio signal generators have reliably calibrated output level controls, but in most cases better accuracy will be obtained if the output level is set with the aid of an oscilloscope or a multimeter. Most multimeters can measure a signal of 1V r.m.s. with reasonable accuracy, provided the test signal is at a suitable frequency. With a 1V r.m.s. input level, VR1 is carefully adjusted for a full scale reading on ME1. The unit is then ready for use.

Do not worry if the meter does not read zero under standby conditions on the 1mV range. The small deflection of the pointer is caused by internally generated noise, plus noise picked up in the test leads and the input wiring. Both types of noise will normally fall to much lower levels when the unit is connected to a signal source and should not significantly reduce the accuracy of the instrument.

PARTS LIST

Resistors (all 0.25w)

R1	100k 1% metal film
R2	10k 1% metal film
R3	1k 1% metal film
R4	100R 1% metal film
R5	11R 1% metal film
R6	180R 5% carbon film
R7	10k 5% carbon film
R8	100k 5% carbon film

(All 0.25W)

Capacitors

VR1	4k7 sub-min hor preset

Capacitors

C1	470n plastic foil
C2, 4	100n ceramic
C3	470n polyester p.c.m.

Semiconductors

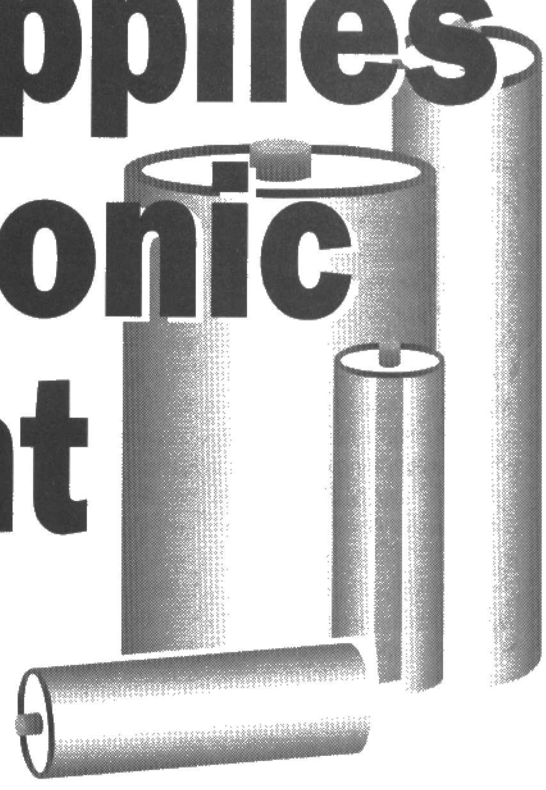
IC1	LF351N
IC2	LF356N
D1, 2, 3, 4	OA91
D5, 6	1N4148

Miscellaneous

JK1	3.5mm jack socket
ME1	100µA moving coil panel meter
S1	12 way 1 pole rotary with end stop (set for 4 way operation)
S2	d.p.s.t. min toggle
B1, 2	6V (4 x HP7 size cells in holder)

Printed circuit board, medium size metal instrument case, battery clip (PP3 type, 2 off), 8 pin d.i.l. holder (2 off), control knob, wire, solder, etc.

Power supplies for electronic equipment



An improved power supply for low signal level electronics, in part 2 John Linsley Hood describes a practical circuit

Electronically stabilised power supplies are of two kinds - shunt and series. The first consists of some device or circuit arrangement which sits like an output load between the power supply output and the 0V line, as I have shown in Figure 1a, and draws an increased or decreased current from the supply line if the output voltage exceeds or falls below some predetermined level. A simple example of such a shunt regulator is a zener diode. The second broad class of voltage regulator circuits is the series stabiliser. This sits between the power supply input and output lines, as shown in Figure 1b.

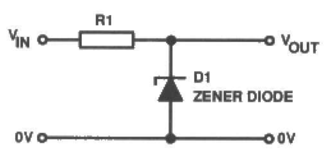


Figure 1a. Simple shunt regulator.

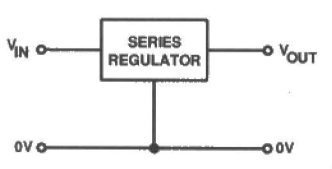


Figure 1b. Series stabilizer.

Both of these stabiliser systems have advantages and disadvantages. In the case of the 'series' arrangement, there must always be some minimum voltage drop between input and output terminals if the circuit is to function. This is known as the 'dropout' voltage, and is typically in the range 2-3V, in the case of the integrated circuit voltage regulators such as the 78xx or 79xx 'three pin' types.

In the case of the 'shunt' stabiliser layouts, some current is always drawn from the supply line by the stabiliser. Also, there must always be enough source resistance to allow the current drawn by the regulator circuit - or zener diode - to pull the output voltage down to the required level and, in the case of a simple zener stabiliser, this means that value of the series resistor must be carefully chosen, so that the control will work without requiring the diode to draw an excessively high current.

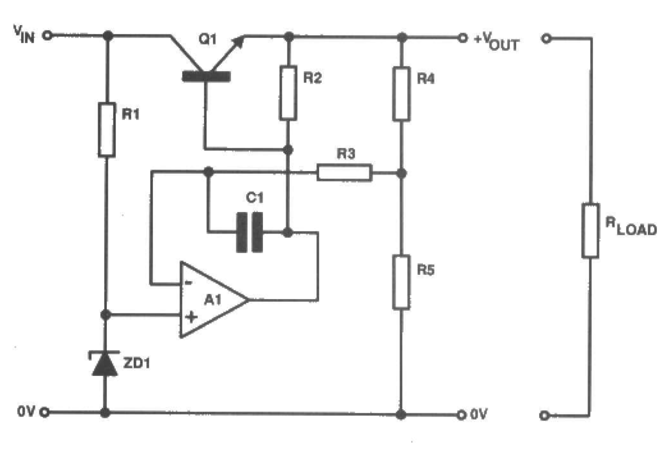


Figure 2. Basic series regulator circuit.

Voltage Regulator Circuitry

A typical schematic circuit layout for a series regulator is shown in Figure 2. In this, a voltage amplifier, A1, is used to compare the output voltage of the circuit - as derived from the voltage divider R4/R5 - with the output from some voltage reference source, which could well be a zener diode and which I have called ZD1. If the output voltage from the circuit becomes too high, the amplifier will reduce the base current drive to Q1, the 'pass' transistor, and the output voltage will then be pulled down by the load (Rl) until it reaches the correct level.

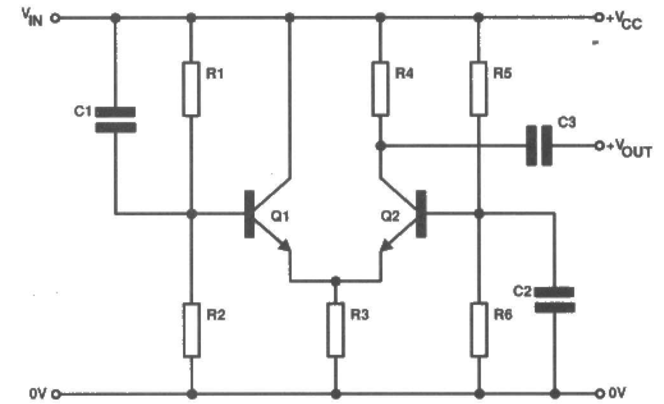


Figure 3. Ripple detector based on long tailed pair

Unfortunately, the feedback loop contained in this stabiliser circuit will usually contain too many elements for the overall phase shift to be within the -180∞ limit required for feedback stability, so some kind of added stabilising component - such as the 'dominant lag' capacitor C1, connected across A1 - will almost always be used to prevent the system oscillating continuously.

This type of stabilisation has the inherent snag that the internal feedback loop gain will begin to fall off beyond some 'turn-over' frequency and the output impedance and ripple rejection will then begin to worsen. In the case of the 78/79xx types of voltage regulator IC, the turn-over frequency is 1KHz and the operating characteristics of these ICs consequently deteriorate as the frequency increases beyond this point - and the frequency range 1K-10KHz is a part of the audio spectrum to which the ear of the Hi-Fi enthusiast is very sensitive.

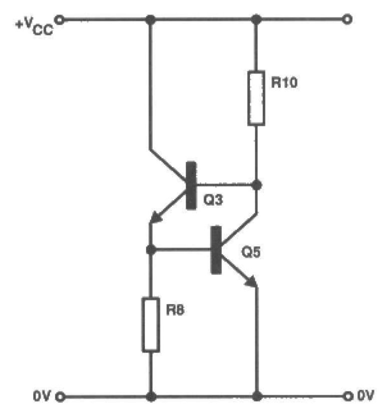


Figure 4. Constant current source

Putting a larger capacitor across the output line than the 0.1-1µF normally recommended will help a little, but usually only at much higher frequencies, well beyond the audio range and in this part of the audio spectrum the humble battery will have the edge, both in terms of constancy of output impedance with frequency and also in respect of its ability to meet sudden current demands without producing unwanted voltage spikes on the supply rails.

Now that most of the other performance shortcomings in audio amplifier design have been made less prominent, signal or distortion breakthrough from one stereo channel to the other, or from later parts of the circuit to earlier, by way of shared power supply rails, is left as an important, but unremedied source of audio degradation. Solid-state circuitry is relatively inconvenient in this respect, because of its ability to generate rapid signal voltage 'spikes' and when these rapid spikes are translated into sudden current demands from the power supply rail, the average IC voltage regulator doesn't cope very well.

This problem will probably be worse on the -ve line than on the +ve, since although the positive and negative rail voltage regulator ICs look much the same devices, and appear to do the same job equally well, the manufacturers of ICs have difficulties in making good PNP transistors, so making a -ve regulator IC by using a simple NPN -> PNP 'mirror image' of the circuitry used in the +ve line device, just isn't possible. In practice the internal circuitry of the -ve rail regulators needs to be elaborated and twisted around quite a lot to make it work like the +ve rail versions, which can usually be built without circuit problems using only NPN devices and therefore usually having a better overall performance.

Nevertheless these IC voltage regulators have several useful internal features, often absent from discrete component DIY jobs, such as an output current/time limit, which will prevent damage to the IC in the event of an output short-circuit, as well as providing a thermal shut-down if the excessive current demand persists for any length of time. They also set the output voltage with reference to an internal 'band gap' precision voltage source, which has much better long-term thermal stability and a much lower noise level than the standard zener diode.

These qualities prompted the question whether anything could be done, as an add-on to an IC voltage regulator, which would reduce the amount of ripple and noise on its output voltage.

An Add-On Shunt Voltage Regulator

There seemed to be no reason why the performance of a voltage regulator circuit could not be improved by connecting

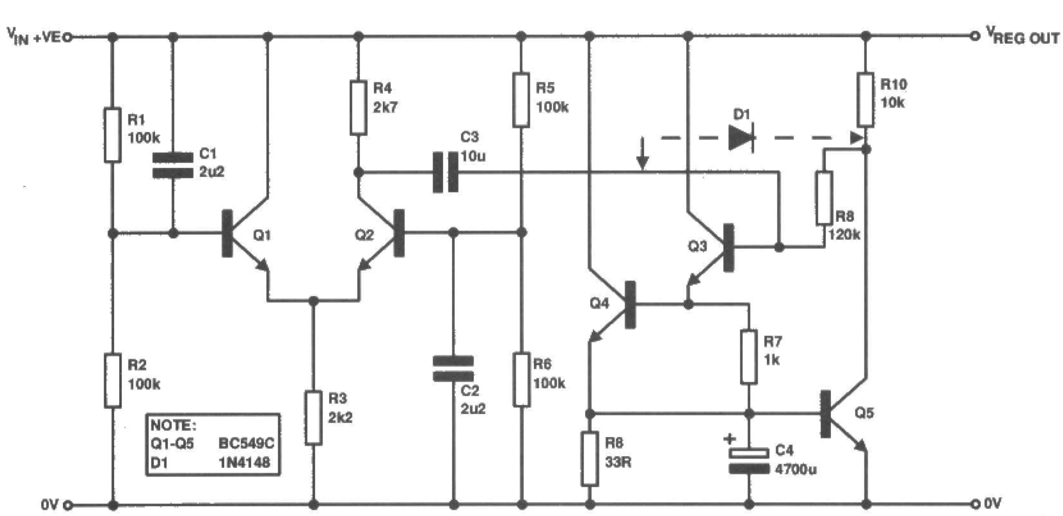


Figure 5. Composite regulator circuit

some external gadget, which would draw a small current from the supply, but which was arranged so that this current could be modulated by any ripple voltage present on the supply line. The aim being that if the output voltage were to momentarily increase or decrease, the current drawn by the external gadget would automatically increase or decrease to oppose these output voltage fluctuations.

Moreover, if the loop feedback circuitry of this add-on gadget was suitably designed, it is possible that this cancellation effect could remain effective over a very wide frequency range and substantially reduce any output noise or ripple voltages present on the supply line.

The circuit adopted consists of two parts: a 'ripple detector' arrangement based on a long-tailed pair, shown in Figure 3, and

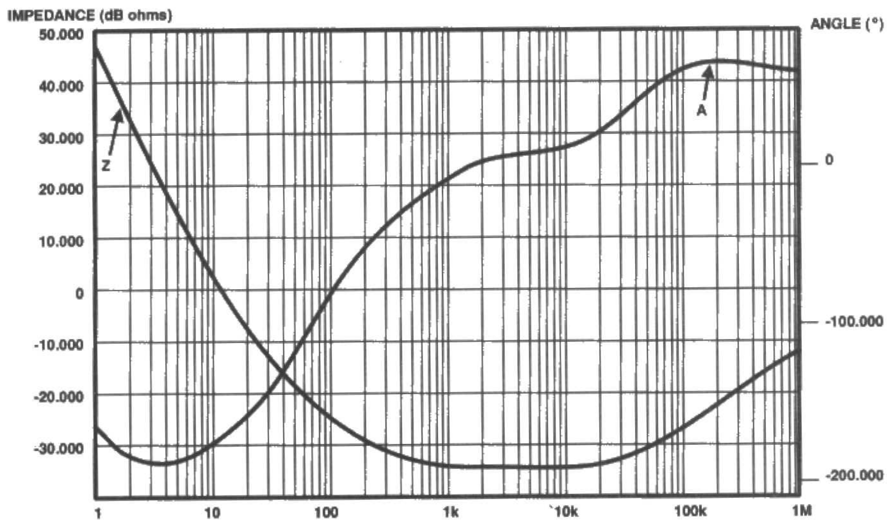


Figure 6. Shunt regulator impedance over frequency range 1Hz to 1MHz.

a constant current source shown in Figure 4, although in order to make its output current capable of being modulated by an AC input control signal, obtained from the output of Q2, this circuit needs to be modified a bit, as shown in the final composite layout of Figure 5. (I have numbered the components in Figures 3 and 4 so that they conform to those in Figure 5).

The working voltage of the circuit shown is determined mainly by the breakdown voltage (Vce) of the transistors used, since, with the exception of C3 and C4, all the capacitors are non-polar and probably will have working voltages of 60V or greater.

The impedance of the circuit at low frequencies depends on the size of the capacitors used, and particularly that of C4, which can be large since it only needs to be 1V working. (In practice this probably means using a 4.7V or 6.3V working component, since lower voltage devices are not often found nowadays).

With the values shown, the circuit generates the electronic equivalent of about half a Farad, and it has an impedance, shown graphically in Figure 6, which is below 0.02 ohms over the range 500Hz - 30KHz, and less than 0.1 ohms over the range 35Hz - 300KHz, even allowing for a realistic value of series inductance in C4, which only influences the characteristics of the circuit beyond about 30KHz. If C4 is made from two 2200µF/4.7V working capacitors connected in parallel, the series inductance of these will only be about 1µH, and the shunt impedance characteristics of the circuit will be less than 0.02 ohms up to some 150KHz.

By comparison, a typical 470µF 25V electrolytic capacitor, with a typical 3.3µH internal series inductance, offers the sort of impedance vs. frequency response, shown in Figure 7, whose lowest impedance is 0.87 ohms at 400Hz and has risen to some 10 ohms at 35Hz.

My own bench power supply has an output noise and ripple level, measured over the range 20Hz - 20KHz, of 300µV. Connecting the circuit of Figure 5 across its output, reduced this to 4µV, whereas connecting a good quality 470µF electrolytic capacitor across the bench PSU output produced no measurable improvement. In a similar experiment, the output noise from a selected 7815 IC voltage regulator was reduced from 60µV, itself better than the makers spec., to 3.5µV, when measured over the same bandwidth.

I am reluctant to claim that this add-on circuit will lead to an improvement in the sound of audio equipment operated from simple IC stabilised power supplies, because I cannot know what

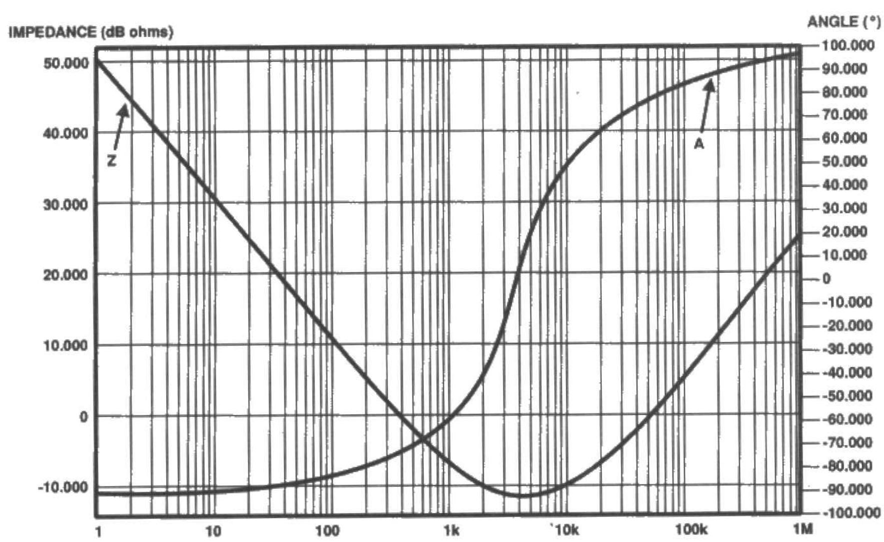


Figure 7. Impedance vs. frequency response of electrolytic capacitor.

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R5&R6 CHANGE TO 4K7 DELETE C2 2U2

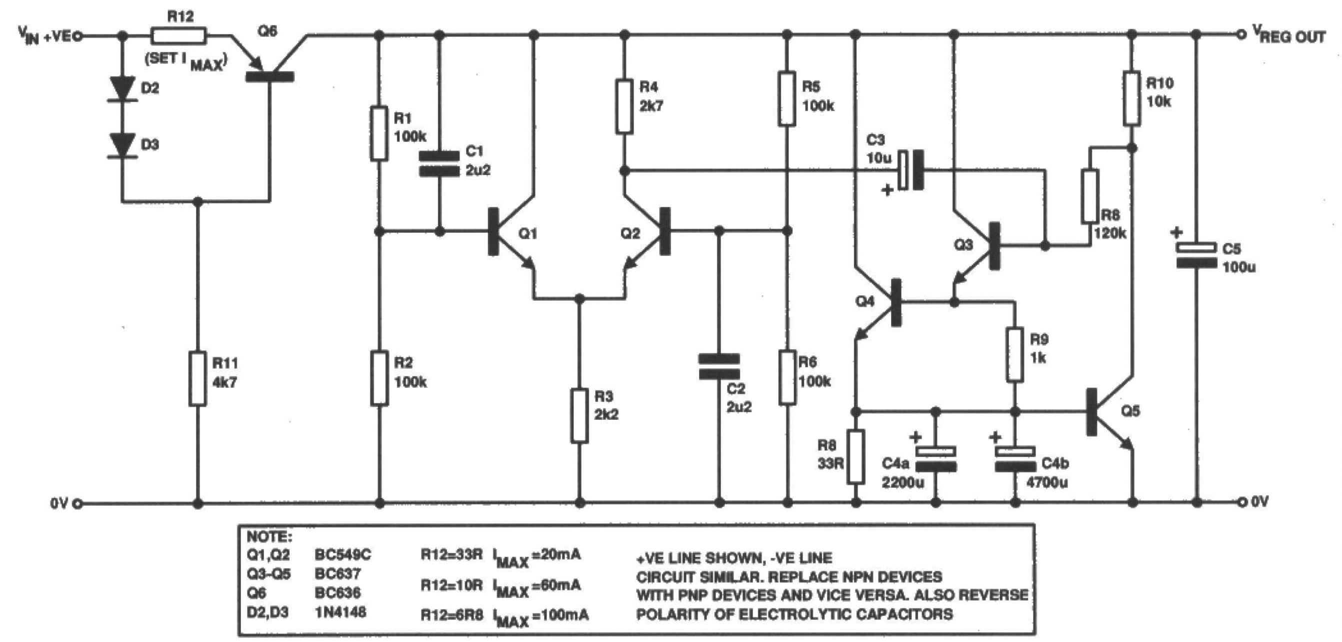


Figure 8. Improved PSU circuit.

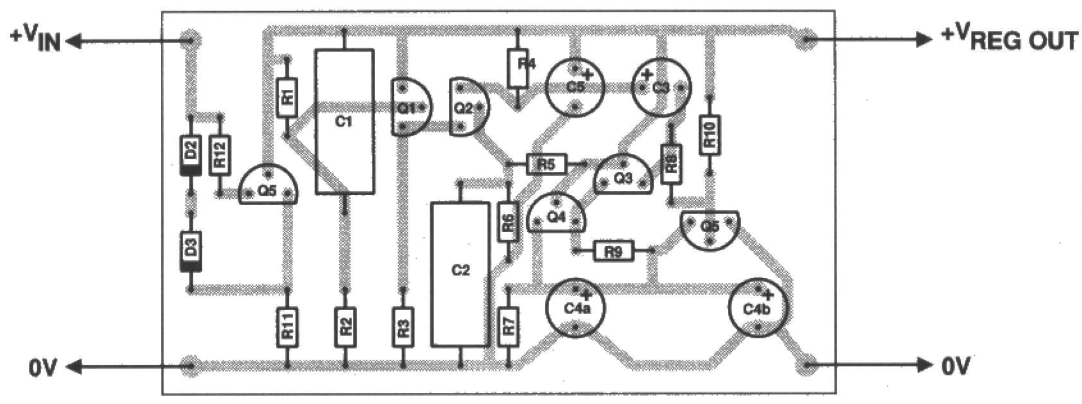


Figure 6. Shunt regulator impedance over frequency range 1Hz to 1MHz.

other people will hear. However, according to my test instruments, it does a useful job. The circuit shown in Figure 5 can easily be translated into a -ve rail version by replacing the NPN transistors with equivalent PNP ones and connecting the electrolytic capacitors (or diode - see later) in the opposite polarity.

The Snag

As all engineers know, there is always a snag and the clever bloke is the one who comes up with the neatest way of getting round it. In this case, the snag is that the circuit of Figure 5 simulates a very large capacitor with an equivalent series resistance of less than 0.1 ohms. So, if one were to connect it across, say, a 20V power supply, on switch-on the circuit would try to draw a current which would have a peak value of 200A, decreasing as the internal capacitors charged up to their equilibrium condition.

If they were allowed to flow, currents of this order would be fatal to Q3 and Q5, through which they would have to pass, and also would be resented by the power supply circuit from which the current was drawn. In my case, initial trials were made using a bench power supply with an adjustable current limit, which I could set to a suitable value. An adequate engineering answer to the problem of the switch-on current surge, is simply to include an input current limiting circuit, as shown in Figure 8. Values for R12 for various current limit levels, up to 300mA, are shown on the diagram.

A somewhat inconvenient effect inherent in this arrangement is that there is a time delay of a few seconds, following switch-on, as the very large equivalent capacitor is charged through the current limited supply.

For those who prefer an axe to a rapier, a simple brute force answer is to limit the surge current duration by connecting a diode, D1, across R9, as shown in dotted lines in Figure 5 and by making Q3 and Q5 TO220-type small power transistors with a base-emitter current rating of 4A, although, since these transistors will have lower values for transition frequency and current gain than the small signal devices originally used, this will somewhat lower the performance of the circuit.

A suitable PCB layout is shown in Figure 9, which can be used with any polarity of power supply by the correct choice of capacitor and transistor (NPN/PNP) polarity.

Microprocessor Fundamentals - Part 4

Alex Stuart continues his series and looks at some of the various ways in which a microprocessor system can communicate with the user

The majority of microprocessor systems will, in their design, involve some form of interaction with the user. In other words they will have to have some form of human interface. How this interface circuitry is designed will depend on the application, but it will also determine how usable the system actually is.

There are two different ways in which a microprocessor system can communicate with the user. It can communicate via its own dedicated input/output circuitry - basically switches for input and LEDs, or some other form of display, for output. Conversely it could simply communicate with a PC or other computer via a serial or parallel data link, with the PC performing all the human interface data input and output.

Generally a link to another computer is used when a large amount of data needs to be transferred, such as uploading or downloading programs, or when the data needs to be manipulated in more sophisticated ways, such as being output in graphical format. Other forms of human interface with a microprocessor system may simply involve selection of a particular function, or a display of current status. This is best performed using local dedicated I/O circuitry and it is this type of user interface circuitry that we shall be looking at this month.

The Simplest Dedicated I/O Circuitry

The simplest form of input and output on a microprocessor is a single LED and a single switch. A single LED display circuit is shown in Figure 1a. In this circuit, the output line from a processor I/O port will probably not provide sufficient power to drive the LED, which means that it is necessary to use some form of driver, in this case one eighth of an ULN 2803 Darlington driver chip. The resistor connected in series with the LED provides the required current limiting to ensure that the LED will work properly. Because the 2803 is an inverter, the LED will light when a logic '0' is applied to the output port and will be extinguished when a logic '1' is applied.

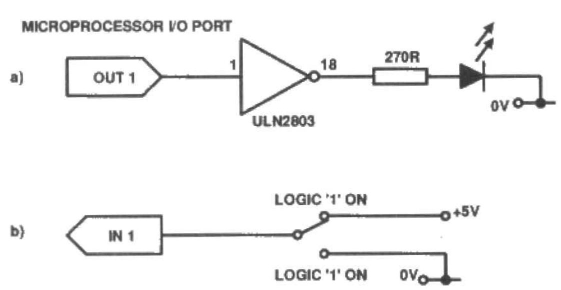


Figure 1(a). Simple on/off led display.

Figure 1(b). Simple on/off switch input

A simple input circuit is shown in Figure 1b. It is based around a single pole, two way switch, the single pole contact being connected to the processor input port and the two way connected to +5V and Gnd respectively. This means that when the processor reads the switch status, it will register either a logic '1' or a logic '0', depending on which way the switch is closed.

These very basic forms of input and output are ideal for switching functions and displaying status. Indeed, some readers may well remember the front panel displays used on early computer systems, such as the first micro based system the Altar 8080 launched in 1976. These early systems lacked any ROM based monitor programs and instead relied on the user entering a 20 byte bootstrap program, using switches and LEDs on the front panel to display and change memory addresses and contents. A front panel could be quite easily constructed using these simple I/O circuits.

Multiplying Output by Multiplexing

If we can switch a single LED on and off, we can also use the output lines from a computer system to display the digits from 0 to 9 on a conventional LED based seven segment display. A simple circuit to drive a single 7 segment display is shown in Figure 2. Since this circuit controls

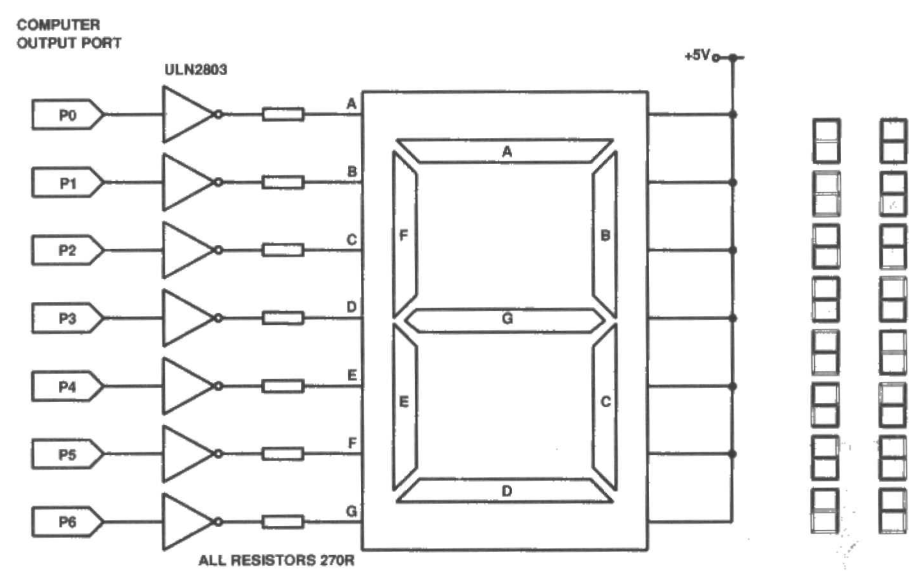


Figure 2. Single 7-segment display where each segment is a separate led.

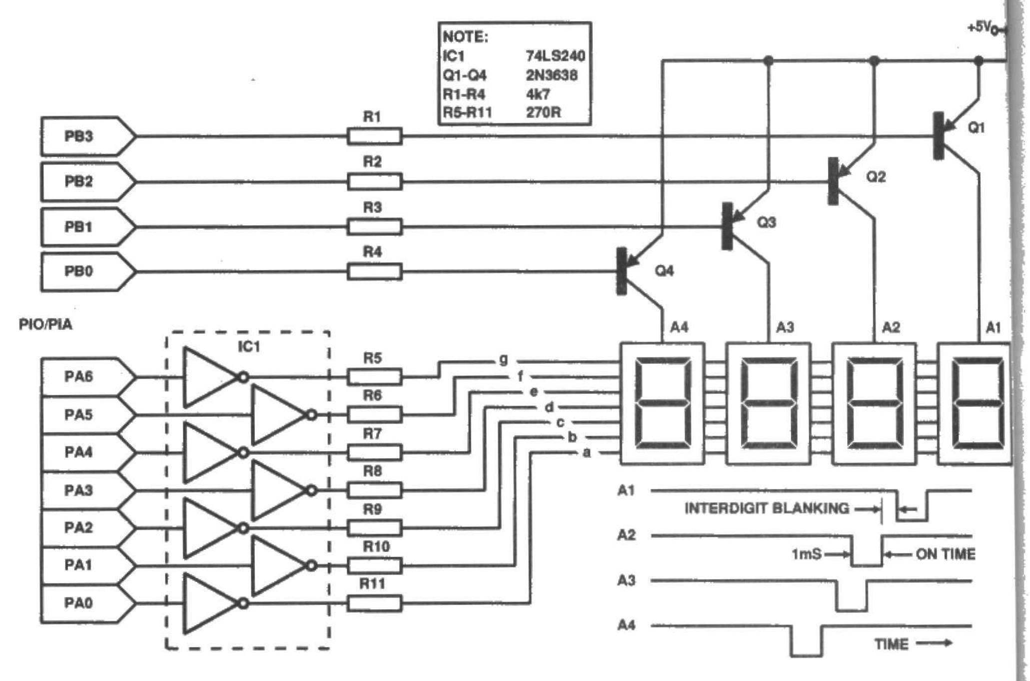


Figure 3. Four digit multiplexed hexadecimal display

every segment we can also use it to output the alpha characters A through to F, thereby enabling output of numbers in hexadecimal as well as numerical format.

Of course, we might very well want to display more than one seven segment character, for example we would need six digits if we wanted to display the time in hours, minutes and seconds. Allocating a separate output port to each digit would be one way of doing this, but given the general scarcity of I/O ports, far from the most efficient way. A far better way is to use a multiplexed display which, in the time display example, would use just two ports instead of six.

As can be seen from Figure 3. a four digit multiplexed display is quite simple to implement. The seven input lines to each of the four seven segment display modules are connected in parallel to the driver chip and thence to the processor output port. Thus, all the segment 'a's are connected together, all the segment 'b's, etc. The common output of each display module would normally be connected to either Gnd or +5V (depending on whether the driver chip is sourcing or sinking the LED display current), in this case connected to +5V via a transistor. The function of these four transistors is to switch the individual display off or on, the switching control being provided by four lines from an output port, each connected to the base of a transistor via a 4.7K ohm resistor.

This circuit allows each seven segment display module to be turned on or off under computer control. In this way, we can turn module one on, then output the data for the segments to be lit in that module. We can then turn the first module off and the second one on, and output the data for the segments to be lit in that module. The multiplexing process thus involves using the on/off switching of the four transistors to rapidly display one seven segment module at a time, in sequence. If we do this fast enough, it will appear to the human eye that all four modules are being displayed at the same time.

The processor will, of course, have to know which segments to turn on and which to turn off. This means that for each number or alpha character that is to be displayed, there will have to be an entry in a character generator table stored in memory, where each entry details which bits are to be turned on and which turned off, thus:

Character	Memory bit 0 1 2 3 4 5 6 7
0	1 1 1 1 1 1 1 0
1	0 1 1 0 0 0 0 0
2	1 1 0 1 1 0 1 0
3	1 1 1 1 0 0 1 0

And so on...

This is a typical example of how software can be used to replace a task that would otherwise be done with hardware. Note that since only seven output lines are needed to supply data to the seven segment displays, bit seven in the above table is left blank. This, of course, assumes that lines 0 through 6 of the output port are actually used - if lines 1 through 7 were used, then the table would be shifted one bit to the right and all the bit 0s in the table would be set to 0.

We can cut down the requirement for output port lines even more if we do not need to display any of the six alpha characters and just confine ourselves to displaying numerical data. We can do this by deriving the seven input lines to the display modules from a BCD to seven segment decoder, such as a 7447. A circuit using this technique is shown in Figure 4 and, as can be seen, it is possible to use this circuit to display a

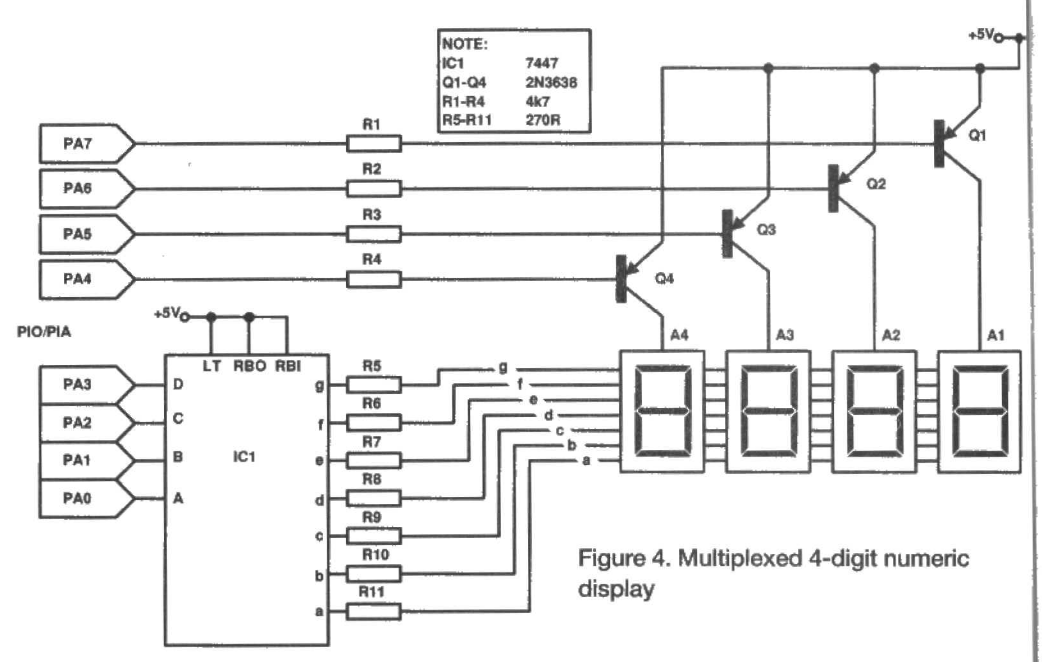


Figure 4. Multiplexed 4-digit numeric display

four digit number using just a single eight line output port. This circuit also has the added advantage that character generation is done by the 7447, the only necessary output being a four bit BCD number.

If a full alphanumeric, or even graphics, display is required, then it could be constructed using 5 x 7 dot matrix displays. Enough modules would be needed to display the message or the graphics image, but the technique of creating such a display is much the same as that used to create the seven segment display.

A simple 5 x 7 dot matrix display circuit is shown in Figure 5. It obviously has too small a resolution to display more than a single text character, but could be used to display symbols or icons of various sorts. The dot pattern would be simply stored in memory as five consecutive bytes, or more if the matrix was made larger.

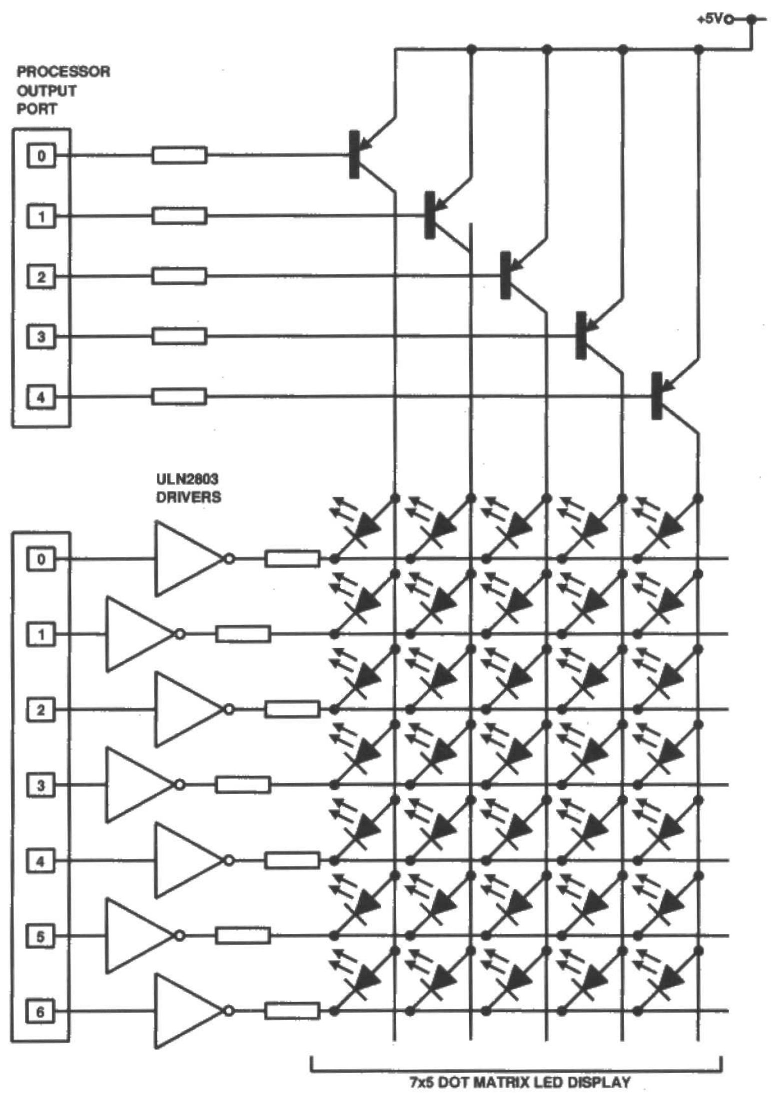


Figure 5. Simple dot matrix display

With a dot matrix display, it is not really practical to use any form of decoding chip, since the number of display permutations is quite large. Furthermore, it is much easier to do it with software. However, when the matrix is enlarged, the number of columns to be scanned may become rather large. In this situation, it is a good idea to use a demultiplexer to generate the column outputs, so a four line to sixteen line demultiplexer chip such as the 74154 could scan sixteen columns, but only use four output port lines. This is shown in Figure 6.

Given the high speed at which the processor operates, it is quite possible to produce large scanned dot matrix LED arrays, the only real constraint being current consumption (the switching transistor must be able to carry the current) and cost. For example one could easily create a display for a solid state oscilloscope using perhaps a 30 x 28 dot matrix. However, at this kind of resolution it is probably better to start thinking of using an LCD graphics display module.

Such modules are widely used in laptop and notebook computers and feature their own in-built character generator and microprocessor controller. This makes interfacing such modules to a computer much easier, and less of a drain on main processor time. They are quite expensive, about £60 for a 256 x 64 dot display, but the best solution where a local alphanumeric or graphics display is required. On the whole though, it is best, wherever possible, to download display tasks of this nature to a communicating PC.

From Switches to Keyboards

Just as we can create an LED display by connecting each individual LED to the output line of a computer I/O port, so we could also create a keyboard by connecting each keyswitch to an input line on a computer I/O port. Fortunately multiplexing comes to our aid once more and there is no need for such brute force techniques.

As can be seen from the simple sixteen key scanned keyboard in Figure 6, we can organise any keyboard in the form of a matrix. In this case it is a 4 x 4 matrix. Four of the lines are derived from an output port and four from an input port. Each key switch will, when closed, make a contact between one of the input lines and one of the output lines. Which input line and which output line are connected form a unique combination, a combination which can be decoded to provide information about which key was pressed.

The keyboard is scanned by toggling each of the output lines in turn. When the output line has been pulled low, the system checks the input lines to see if any of them has also gone

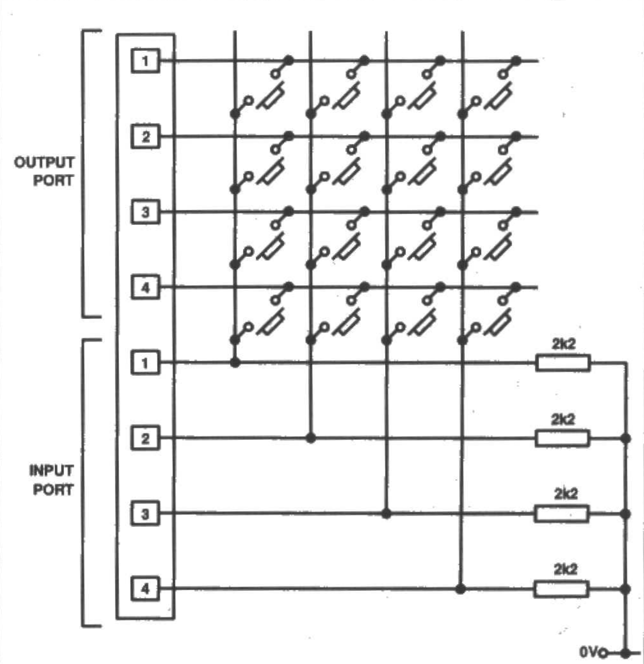


Figure 6. A simple scanned matrix keyboard.

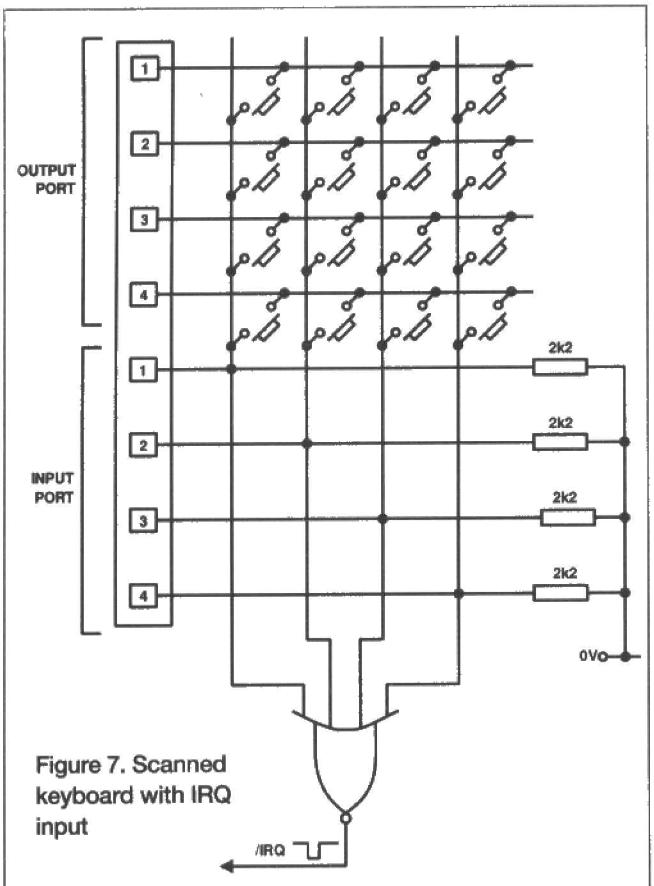


Figure 7. Scanned keyboard with IRQ input

low. If one has, then the system has identified the fact that one of the keys has been pressed. The combination of the binary value on the output lines and the value on the input lines can then be used as the index on a look up table, which will tell the system which key has been pressed and assign to that key press some appropriate value or action.

You will find scanned matrix keyboards of this sort on all kinds of equipment, including push button phones and calculators (when scrapped, both of these make good sources of such keyboards). Some of these use decoder chips, but once again there is little need for such extra hardware since the task is very easily performed by software. On large matrix keyboards, a demultiplexer such as the 74154 attached to the output scanning lines will reduce the need for I/O port lines.

In order to further reduce the need for I/O port lines, some commercial systems actually combine the scanning output for the display with that for the keyboard, thereby making the same circuitry perform two tasks.

Problems with Keyboards

There are several problems associated with keyboard inputs. Firstly, knowing when they take place, secondly guarding against multiple concurrent keypresses and lastly, overcoming the problem of keybounce, which can all too easily generate spurious multiple keypresses.

The problem of knowing when a key is pressed can be approached in one of two ways. We can regularly scan the keyboard, say ten times a second (this should be ample to catch all key depressions, since the average human keypress on a keyboard is between one tenth and one second in duration) and check for the depression of any key. Or we can add some simple hardware to the system which will cause any keypress to generate a system interrupt, which will then initiate a keyboard scanning procedure to find out exactly which key was pressed.

For most small simple systems, the interrupt method is probably the easiest and best. It obviates the need for additional circuitry to provide the regular interrupt that calls the keyboard scanning routine and also frees the processor from the overhead of checking the keyboard, often a very important consideration in speed sensitive applications.

Generating an interrupt when a key is pressed is actually quite simple, providing we are not using a demultiplexer. If we leave all the output, row, lines high, then pressing any key on the keyboard will send one of the column input lines high. Connecting all the column lines to a NOR gate, as shown in Figure 7, will then generate a negative going IRQ pulse whenever any key is pressed, thereby initiating the keyboard scanning routine.

Eliminating multiple concurrent keypresses, or the user simply holding a key down for an unduly long time, is a function which must be included into the keyboard scanning routine. The way to do this is to make a rule that a valid multiple entry will only be accepted when the keyboard input has returned to 'zero', thus differentiating between two successive characters. This way, if we want to type 99, there has to be two distinct keypresses rather than one continuous one. The way this can be done is shown in the flow chart in Figure 8. By storing a record in 'STATE' of what key was last pressed, as well as the fact that a key was pressed, we can solve the problem of two keys pressed at the same time, thus providing two key rollover.

Keyboard bounce is a problem which can also be solved using software. The problem is caused by the fact that when a switch is closed, the contacts will tend to bounce for a few milliseconds. Normally, this would be unimportant but with a system clock running at several megahertz, a few milliseconds is a very long time and more than sufficient to generate a multiple character input thanks to the bouncing contacts on the keyboard.

The only way to overcome this problem is to use a fast sampling loop to repeatedly look at the state of the line attached to the key. Only when the state of that line is steady over a number of cycles through the sampling loop will it be accepted as a valid keypress.

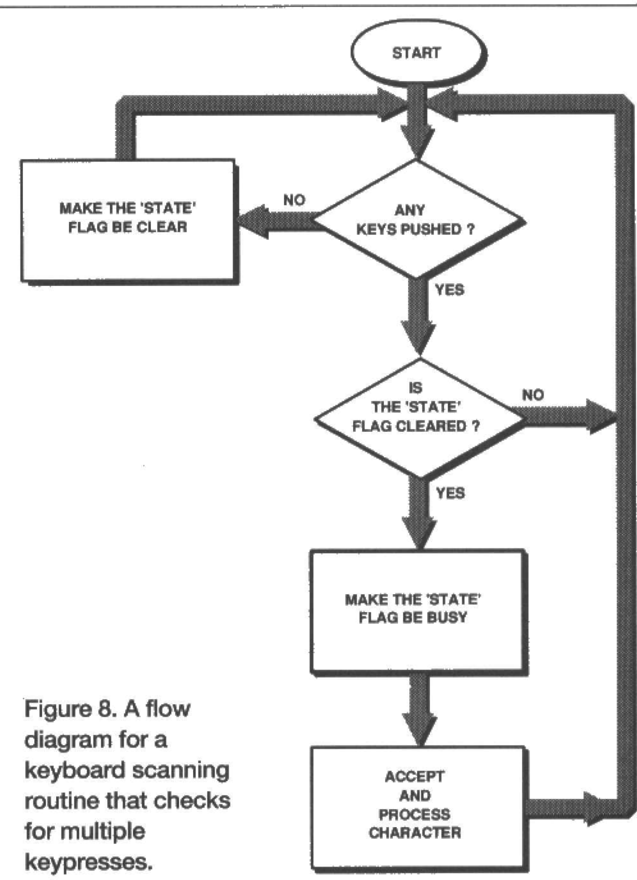
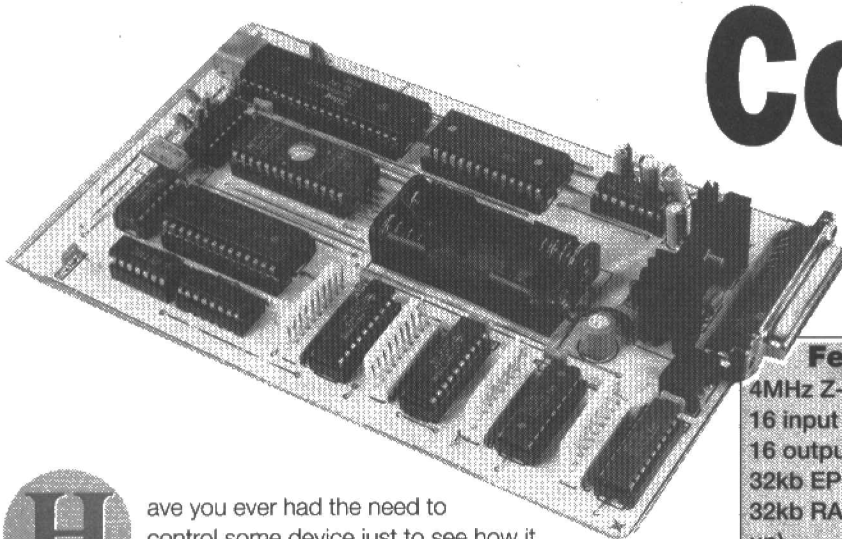


Figure 8. A flow diagram for a keyboard scanning routine that checks for multiple keypresses.

Next month... We will look at parallel and serial communications between a microprocessor and a computer.

An Experimenter's Computer



Build Jim Spence's inexpensive and versatile FORTH computer

Features:	
4MHz Z-80 processor	FORTH compiler and Z-80 assembler in EPROM
16 input port lines	Low cost - under £30
16 output port lines	
32kb EPROM	(note if you do not wish to use FORTH, then this board is an excellent basis for any low cost, versatile, stand alone processor system)
32kb RAM (battery backed up)	
RS232 port	

Have you ever had the need to control some device just to see how it works? A stepper motor, flashing lights display, pulse decoder for a radio clock?

The best way to do this, by far, is to use some kind of micro-controller. In a professional environment, a company can purchase a development system from the chip manufacturer with all the hardware required and special development software built in. This, of course, is out of the question for amateurs. So, wouldn't it be nice to have some kind of low cost development system that allowed us to experiment in a totally interactive environment? Most enthusiasts have access to a computer capable of supporting serial communication, in the form of RS232 and this is all you need to use this Z80 based experimenter's board.

The hardware is not particularly spectacular, as Z80 was chosen because it's cheap. There are a lot of people who know Z80 assembler (although this is not necessary) and it's very easy to get hold of. Discrete components were chosen for input/output, rather than the purpose made Z80PIO, again to keep the cost down. Also, because it's an experimenter's board, the I/O chips are likely to get damaged and these are cheaper to replace than a PIO.

The software is what makes this board special. In other development boards, you need to learn the assembler language for the particular micro, write the code, assemble it, download it to an EPROM blower or emulator, test it and then resume the cycle again. In this system you can develop an application in either a high level language or assembler (both are built in). This can be done fully interactively - for example, you can cause LEDs to light up or motors to turn by typing the appropriate words at the keyboard. When you have developed an application, type "AUTO" and the board will work stand-alone for as long as the batteries supply power to the CMOS RAM.

It is intended that a range of projects can be produced for this board and among them may be:

LCD Display
Keypad Input
Stepper motor interface
Capacitance meter
Portable teletype

Hardware

The hardware is extremely straightforward and has been designed with cost in mind. IC4 A to C form a clock generator, along with crystal X1. It is an unusual frequency of 7.32728 MHz in order to generate an accurate Baud rate for IC10. IC5 is a divide by 12 counter, the first stage of which is a divide by 2 giving the CPU clock. The RAM and ROM areas are evenly divided into the available address space of the Z80 CPU. The ROM begins at 0000h and ends at 7FFFh and the RAM begins at 8000h and ends at FFFFh. This address space is decoded by address line A15 and gated with the MEMRQ signal.

Battery backup is provided by 2 x 1 5V dry cells, B1. At power down the RAM's chip enable (20) and power supply pin (28) need to be held high. This is done by a simple diode and resistor arrangement, which has proved quite satisfactory.

Note that it is important that only a 7402 device is used. A 74HCT02, LS or HC type either pulls the output pin low when powered down or consumes a heavy current. Although the arrangement is simple, it was found that the batteries could be changed without the loss of program data. Increasing the size of C4 would give an even greater safety margin.

Input/output decoding is carried out by IC7 and address lines A1 to A3 with the IORQ signal. This arrangement gives an address map which goes up in twos, see table 1. The choice of I/O device was governed by the fact that this is an experimenter's board and it is much cheaper to replace a single 74HC574 than, say, a Z80PIO or an 8255 I/O device. You can also have as much or as little I/O as you like (up to the maximum on the board) simply be inserting or leaving the device out.

An RS232 interface is essential to this board and this is provided by an 8251A (IC10) in conjunction with IC13. The clock is derived from the divide by 12, which produces a frequency of 614.4 kHz. This is then divided internally by 64, by IC10, to give a Baud rate of 9600. Further divisions to the clock frequency could have been made, which would have given a choice of Baud rates, but this would have added to the overall

cost. It is important that the 8251, type A, is used as this is able to operate with a clock frequency of 615kHz.

The RS232 interface is provided by IC13. If your terminal or computer can accept 5V signals, then this can be omitted.

TABLE 1

I/O Addresses

0 & 1	IC8	(output)
2 & 3	IC11	(output)
4 & 5	IC7	(input)
6 & 7	IC10	(input)
8 & 9	spare	
A & B	spare	
C & D	spare	
E	IC12	(data)
F	IC12	(control)

Serial Interface

To avoid the usual trouble with RS232 serial interfaces, no hand shaking has been implemented. The clear to send line has been grounded on the board for this purpose. If you are connecting the board to a PC, pins 5, 6 and 20 will need connecting together at the PC side.

PC	BOARD
female	male
2	2
3	3
7	7
5	I
6	I
20	I

Software

Built into the firmware is a programming language which could have been specifically designed for controlling small CPU boards. It is a completely interactive high level language. Unlike BASIC it is a Compiled language, which means that it is much faster. If you need real time or speed, then there is a built in Z80 assembler which actually assembles the code as you type it in. When you are happy with the application you have designed, you can make the firmware run your program at switch on, thus providing a completely stand alone application.

So what is this high level language? Well, if you promise to keep reading, it's FORTH. Unfortunately, this word, among anyone who has ever programmed, provokes violent reactions either for or against it.

I firmly believe that you should choose a language to suit your application. It is true that you can write a database application in FORTH but why, when there are several languages specifically designed for this task, dBASE to name but one. Likewise, it is not practical or feasible to program a small board such as this in dBASE. C is used for many things, with control being one of them, but for sheer interactiveness and speed of development, not to mention compact size, for this type of application there is nothing to beat FORTH.

Computer Requirements

The board needs connecting to a terminal. This can be either a stand alone terminal or, more likely, a computer running some Comms. software. For simplicity, only transmit and receive have been implemented, no handshake is required and it is a fixed Baud rate of 9600. An IBM PC computer is ideal, running the windows Terminal program.

Construction and Testing Procedures

Use sockets for all the ICs. It really is a false economy not to and it gives you that peace of mind, knowing you can replace any suspect component. If you are using a PCB, then just make sure there are no dry joints or shorted tracks.

To keep costs down, a single sided board has been used, but the penalty for this is all those links. If you are making the board yourself, then a good idea is to make a copy of the top side of the board and accurately glue it to the top of the PCB, effectively giving a cheap form of silk mask.

Put the links in first. Insulated wire should be used for the links, which are shown dashed. Make sure all the links are in place before inserting any sockets. Solder in all the components but don't insert any ICs.

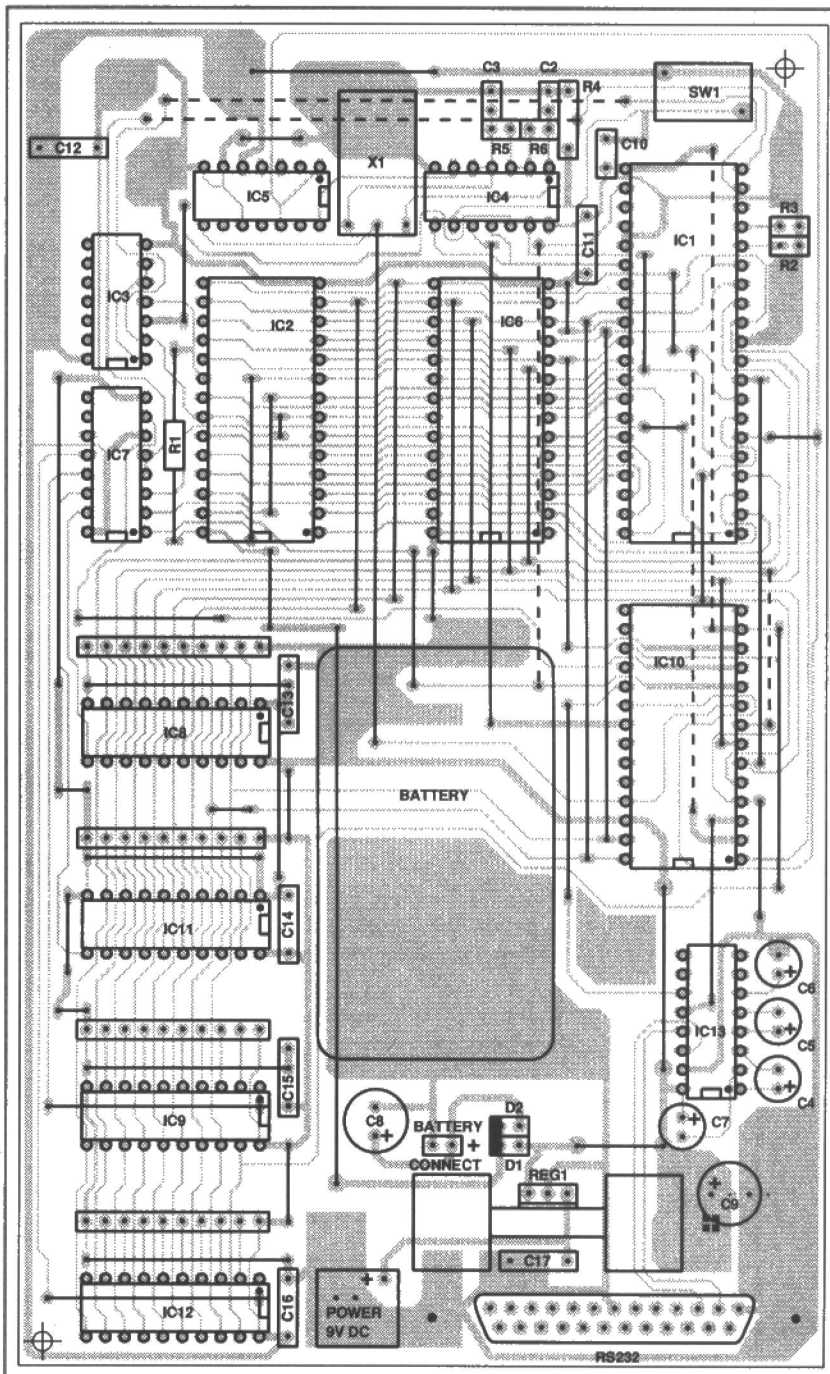


Figure 2. Component overlay for the Forth computer

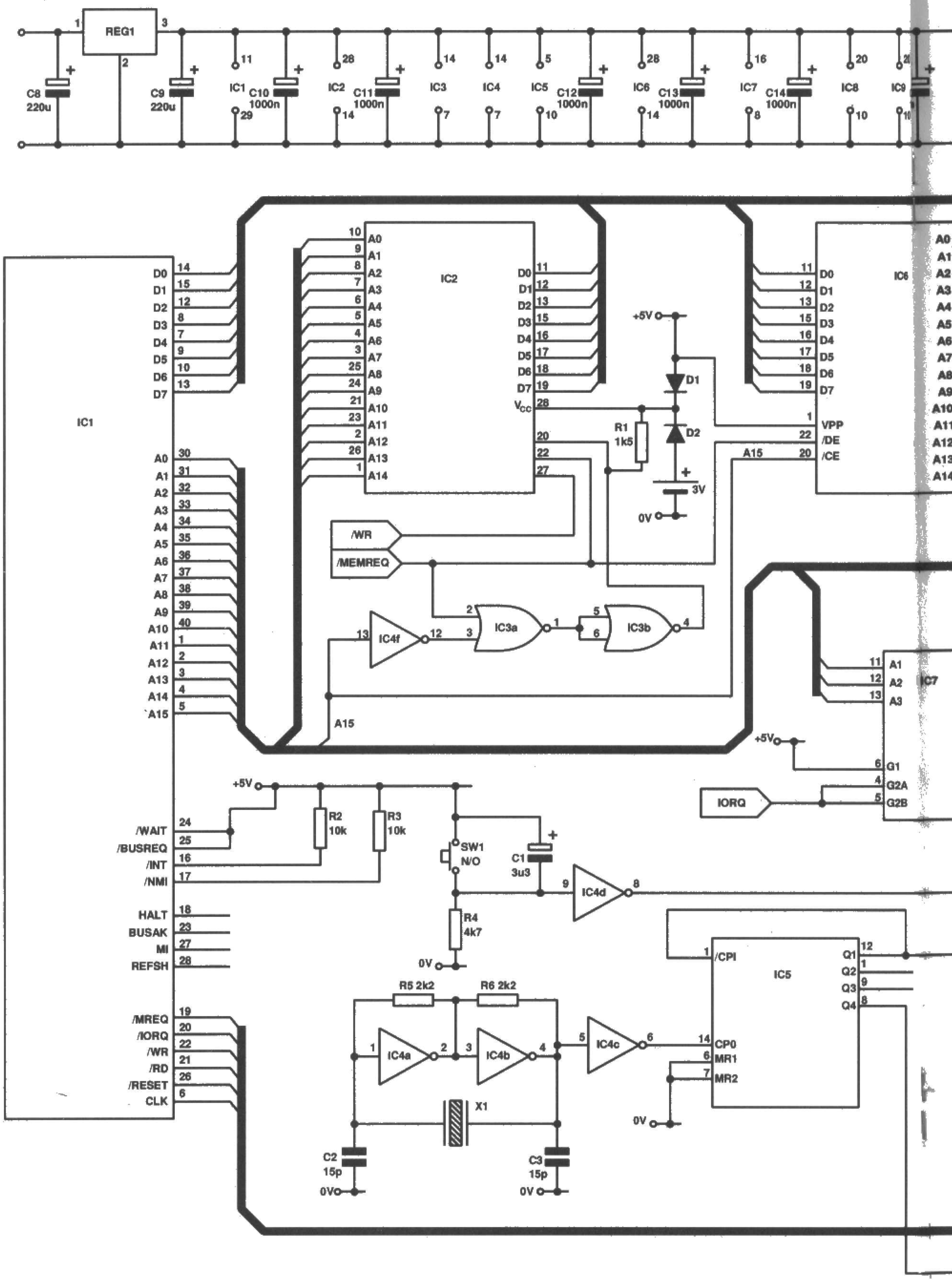
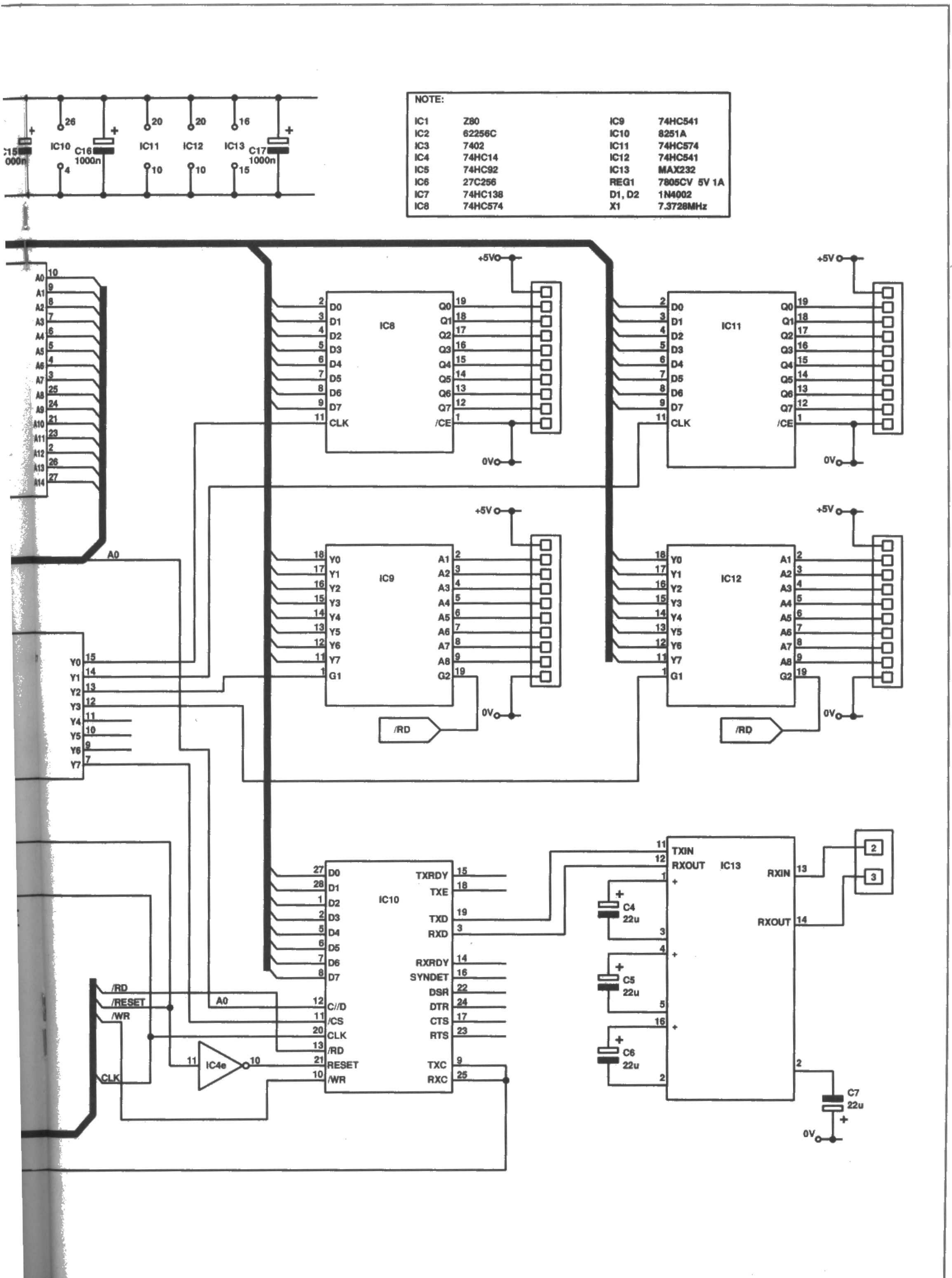
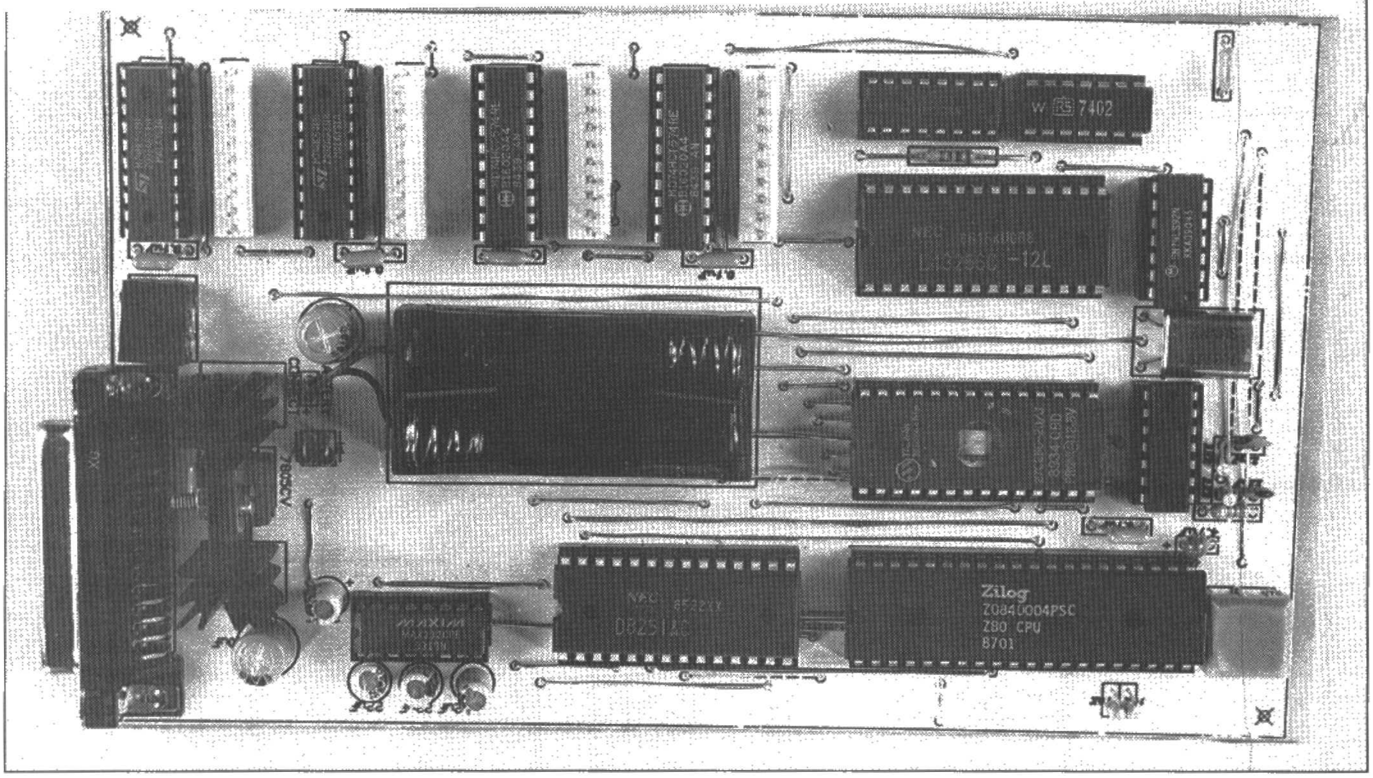


Figure 1. Circuit diagram for Forth computer



NOTE:

IC1	Z80	IC9	74HC541
IC2	62256C	IC10	8251A
IC3	7402	IC11	74HC574
IC4	74HC14	IC12	74HC541
IC5	74HC92	IC13	MAX232
IC6	27C256	REG1	7805CV 5V 1A
IC7	74HC138	D1, D2	1N4002
IC8	74HC574	X1	7.3728MHz



Before inserting any ICs, connect the power and test all the sockets for the power supply and correct polarity. Now insert IC4, IC5 and the crystal. Power up and test for a clock signal. Use a scope or logic probe or, if you are on a very tight budget, a transistor radio placed anywhere near the board will howl and whistle if the clock is working. If it is not, then it is simply a matter of checking the wiring and connections. As a last resort, change the ICs.

Once the clock is working, disconnect the power and insert IC1, IC3, IC6 and IC7. Connect the power again and pin 15 of IC7 should be slowly pulsing high and low (half second high and half second low). This is a diagnostic check indicating that there is no RAM present. The IORQ line of the processor should also be pulsing. If this is not the case, check the reset circuit and see that it delivers a negative going pulse when the button is pressed. Some of the low address lines should be pulsing and the data lines should also be pulsing. Check for short and open circuits in the data and address bus. The chip enable pin (pin 20) to the RAM should be high and the chip enable pin to the ROM should be low.

Following the above, it's now time to test the RS232. The board has been design to transmit on pin 3 of the 25 way connector (pin 14, IC13) and as such, with the board powered on, pin 3 should be a steady 10V negative. Insert IC10 and IC13. Observe this voltage with an analogue meter and press the reset button. The reading should deflect towards 0V for about one second. This is the message telling you that there is no RAM on board. All being well, connect up to your RS232 interface, making sure that your computer is expecting to receive signals on pin 3. Set your Comms. program to 9600 baud, no parity, 8 bits and two stop bits. Make sure any hand shaking is switched off and press reset again. You should see a message informing you that there is no RAM in the system. If you have got this far and are not getting any message on your computer screen, then it is the interface between the board and computer, or the Comms. program you are using which is at fault.

Assuming the board is working so far, insert the RAM, IC2 (powering off first) and you should get the sign on message followed by "ok [H]". Pressing return on the keyboard will result in the board returning "ok [H]". We are now ready to begin.

Next month ...

We will be looking at implementing the control software, the FORTH compiler and Z-80 assembler as well as giving a full introduction to programming and using FORTH to control external equipment.

PARTS LIST

Resistors

R5, R6	2k2
R2, R3	10k
R4	4k7
R1	1k5

Capacitors

C2, C3	15pF
C10-C16	0.1μF
C1	3.3μF
C4-C7	22μF
C8, C9	220μF

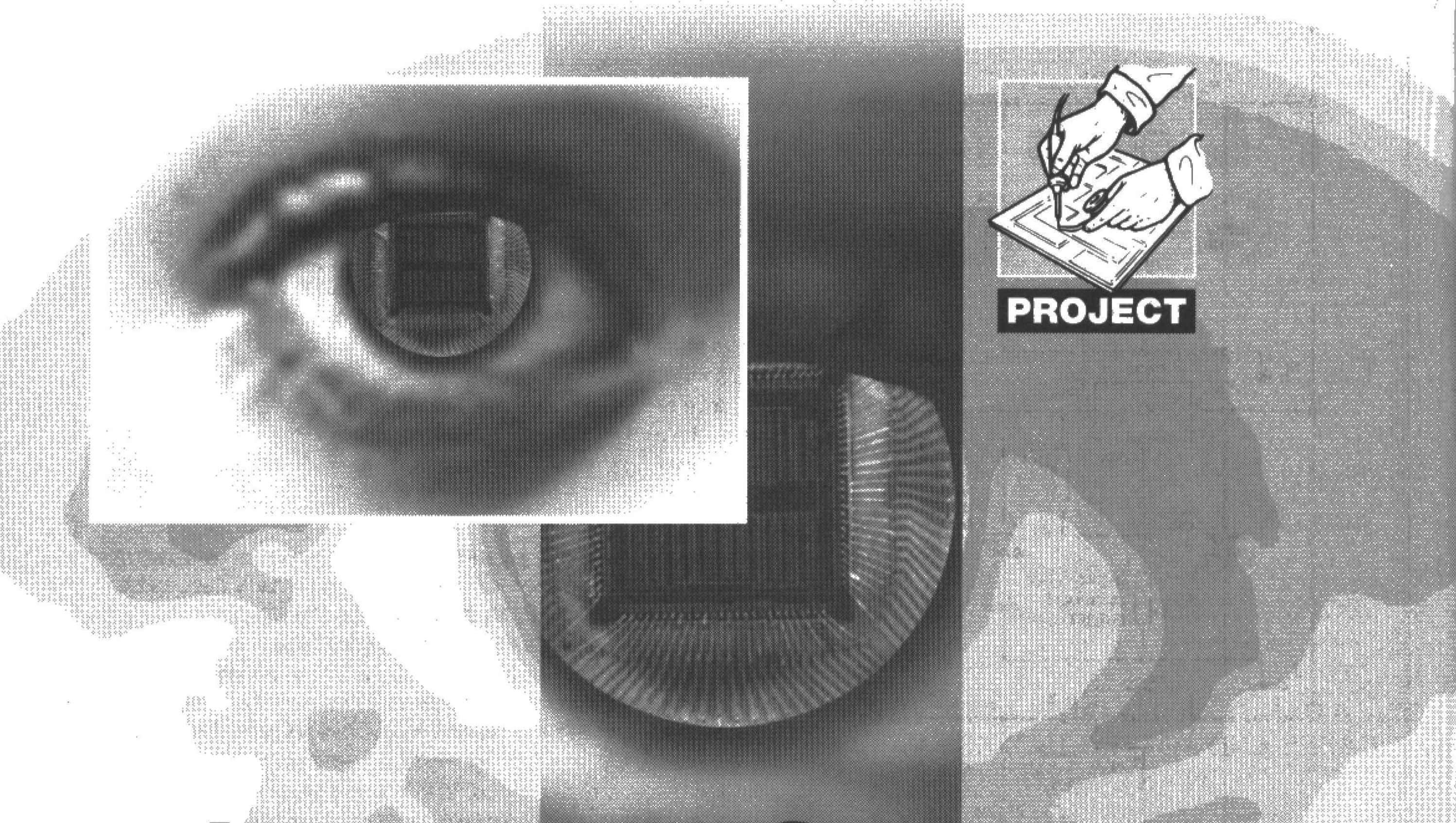
Semiconductors

5V 1A Regulator	7805cv
IC1	Z80
IC2	62256C
IC3	7402
IC4	74HC14
IC5	74HC92
IC6	27C256
IC7	74HC138
IC8, IC11	74HC574
IC9, IC12	74HC541
IC10	8251A
IC13	MAX232
D1, D2	IN4002
Crystal	7.3728MHz

Miscellaneous

1 Battery Holder (2 x AAA)
1 Heat sink
1 25 way female angled D connector
1 9V Power socket
3 14 Pin Sockets
2 16 Pin Sockets
4 20 Pin Sockets
3 28 Pin Sockets
1 40 Pin Socket
4 10 Way SIL pins
1 PCB

PROJECT



An eye for a robot

Optical sensors can help a robot find out about the world around it. In Part 2 of this series, Nick Hampshire looks at a simple but practical vision system

Last month we looked at some ideas, as well as the circuitry, for a simple light sensing system that can be used by a robot to help it navigate around the world in which it 'lives'. Sensors which can also be used to enable the robot to search for light or dark coloured objects, or follow a white line painted on the ground, even to track moving objects, such as a man in a white coat. This month, we look at assembling such a system and some basic software which will allow it to 'see' the world around it.

Starting Construction

On projects of this sort, especially when they are subject to on-going development, I have a preference for Veroboard as the constructional medium. It has the advantage of being cheap and is relatively easy to design simple circuit layouts (the cardinal rule when using Veroboard is never try to cramp a circuit onto a board which is too small, far better to leave a lot of empty space). Veroboard also has the advantage that, providing one socket mounts ICs and leaves reasonably long leads on other components, it is easy to remove components and recycle them for a new version on another piece of Veroboard.

So, construction of the Robot Eye Version 1 was on four pieces of 4 x 4in Veroboard (I just happened to have some pieces of this size available).

Construction was started with the power supply. Figure 1 shows the circuit diagram (repeated from last month) and Figure 2 shows the Veroboard layout for this circuit. Once the components have been soldered to the board and all appropriate track cuts made, it should be visually inspected for solder bridging tracks, etc. A meter set to check resistance can then be used to check that there is no short circuit between ground and the positive voltage input, or between ground and any of the three positive voltage outputs.

Before connecting the board to a DC power supply, this could be a bench PSU or a battery with a voltage output between 15 and 20V DC, the three preset potentiometers on the board should be set to the middle of their range. Power can now be applied. With the meter set to measure DC voltage, check that there is a voltage output from each of the three outputs. Then, using the meter, adjust the potentiometer on each output circuit so that the output is the required voltage. The three output voltages should be +5V, +6.2V, and +12V and all three should be able to provide at least 500mA of regulated power output, sufficient for both the motor and the circuitry.

The Motor Control Board

With the power supply board up and working, we can now start on construction of the other three boards. Since it is the simplest and the easiest to test, it is a good idea to start with the motor driver board, the circuit diagram for which is shown in Figure 3 and the Veroboard layout for the circuit in Figure 4.

Once this has been assembled and the appropriate tracks cut, it should be carefully visually checked to see that the

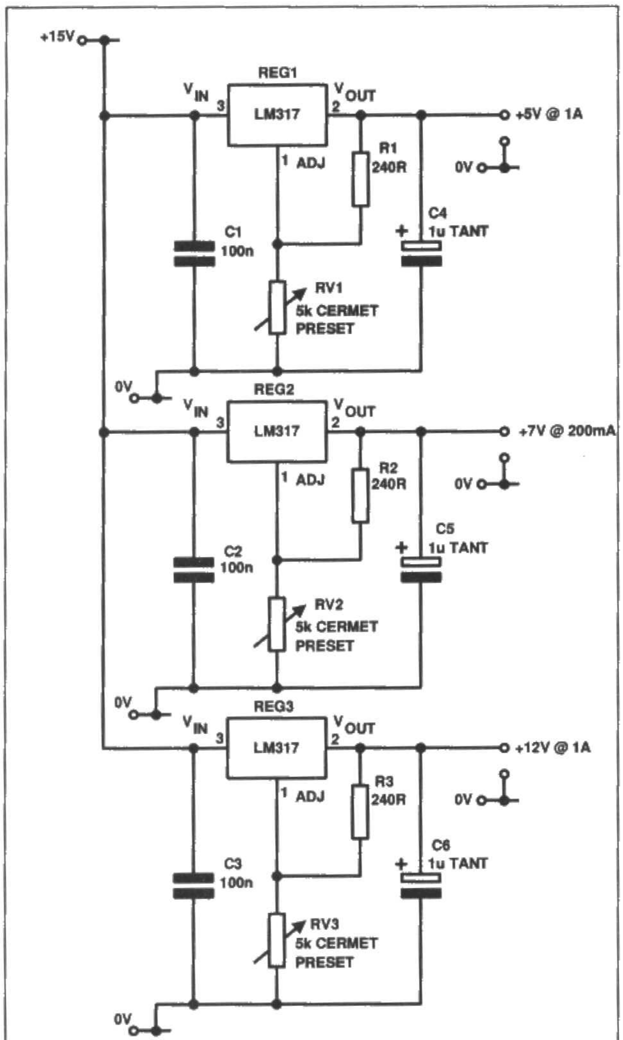


Figure 1. Power supply curcuit.

layout is correct and that there are no unintentional solder bridges between tracks. Then, before inserting the ICs into their sockets, a meter should be used to check that there are no short circuits between any of the power supply rails and ground. If the meter shows a high resistance, then the ICs can be added, taking great care to ensure that they are in the correct orientation.

The motor should then be attached. Here, care should be taken to ensure that the correct connections are made The colour codes on the circuit diagram are for the stepper motor supplied by Maplin, although a small surplus stepper motor from a printer or other piece of scrap equipment will work just as well. In this case, a meter should be used to help identify which leads are which, though you might find some trial and error necessary.

The circuit can now be attached to the I/O port of a PC parallel I/O board (I use Maplin's Programmable PC I/O card and the software used in this article is based on this 24 I/O line 8255PPI card, positioned in I/O address location $300 hex - the default location for such cards).

Since the motor driver board uses the three 7407 buffers, it can be directly connected to the I/O board output port, in this case the three least significant lines of port C (the line connections are shown on Figure 3). However, I personally prefer to add Darlington drivers to all the output lines so that they can also drive an LED as well as the circuit under control, making it easier to see what is happening. An octal Darlington driver IC, like the ULN2803A, is ideal.

With the motor attached to the circuit, 5 and 12V power applied and the control inputs attached to the PC I/O board, it is now possible to test the board. We can do this by writing a small program, one which causes the motor to turn twenty steps (on this motor, each step is 7.5 degrees, other motors may have different step angles) to the left and then twenty steps to the right and repeatedly back and forth. The test program, written in Microsoft BASIC, is as follows:

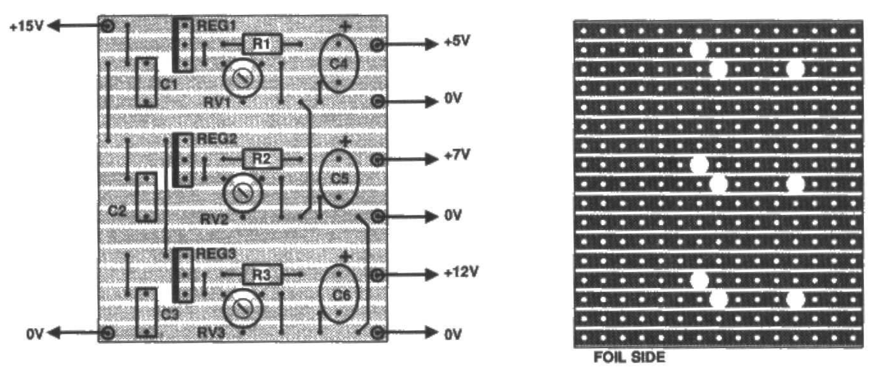


Figure 2. Power supply veroboard layout.

```
1 REM Motor test program
10 BASEADD%=&H300
20 OUT BASEADD%+3,128
30 REM Start turning twenty
   steps anti-clockwise
40 FOR Q = 1 TO 20
50 OUT BASEADD%+2,2
60 FOR I = 1 TO 200
70 NEXT I
80 OUT BASEADD%+2,3
90 FOR I = 1 TO 200
100 NEXT I
110 NEXT Q
120 REM Start turning twenty
    steps clockwise
130 FOR Q = 1 TO 20
140 OUT BASEADD%+2,0
150 FOR I = 1 TO 200
160 NEXT I
170 OUT BASEADD%+2,1
180 FOR I = 1 TO 200
190 NEXT I
200 NEXT Q
210 GOTO 30
```

This is, of course, a very simple control program and one primarily designed to test the circuit.

Note the use of the FOR...NEXT loop, with the variable 'I' to generate a delay between each output. This is necessary to ensure that individual discrete steps are made and to allow the motor to come to a stop before the next step is made. Note also that only lines 0 and 1 are used, the Reset on line 3 is often not used at all and could be connected to the +12V line. This means that toggling line 0 up and down will generate the actual steps and the steps will be in a clockwise direction if line 1 is at logic 0 and anti-clockwise if it is at logic 1.

If you encounter problems, first check the output from the computer - this is where LEDs on each output line come in handy. Then check that the correct lines are connected to the circuit, as it is very easy to connect them the wrong way round. Then, with the SAA1027 removed, check the outputs from the 7407 (a miniature low power LED soldered to a 1.2k ohm resistor, with the cathode attached to the ground line, makes a handy little logic probe for doing this, although never leave it attached to any component for too long, since it may draw too much current and damage the device). Finally, replace the SAA1027 and

remove the motor, then test the output from the SAA1027 (again the LED probe can be used). If the circuit checks out, then the problem may well lie in the stepper motor being connected wrongly or even being of the wrong type.

With the stepper motor working under computer control, it can be mounted on a small bracket that is attached to a solid base, such as a block of wood. The bracket should be such that the motor shaft points vertically upward. A small pulley, gear or wheel, should then be attached to the shaft to act as the base for the sensor optics. Thus, when the motor turns, the optics will scan back and forth, left to right then back to the left and so on.

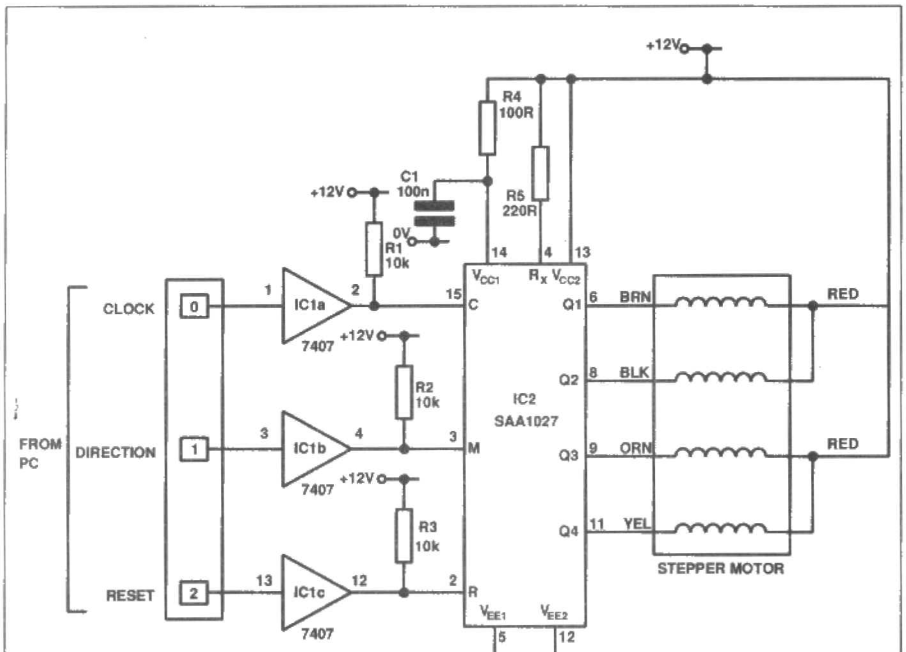


Figure 3. Stepper motor control circuit.

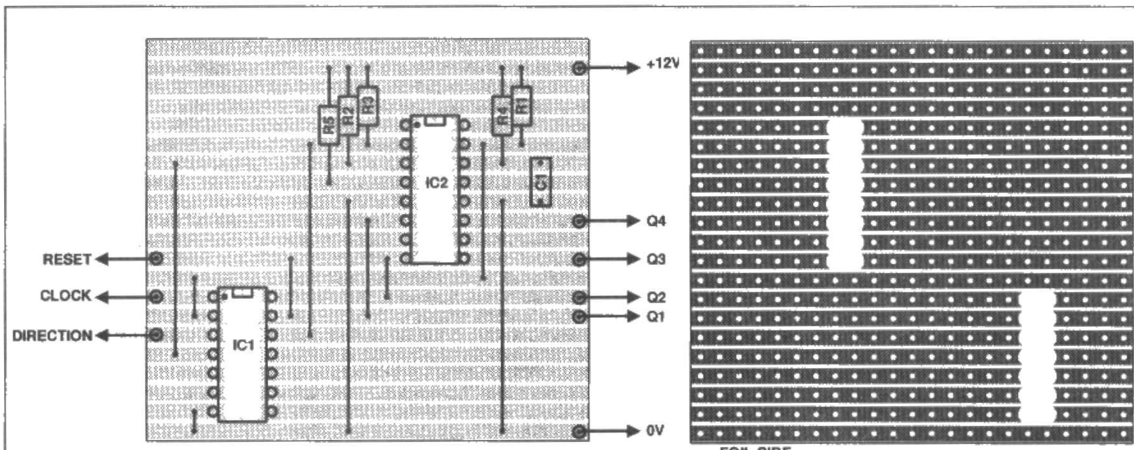


Figure 4. Stepper motor control veroboard layout

Building the Analogue to Digital Converter.

The analogue to digital converter circuit is more complex than either of the other two circuits so far constructed. This is because it involves both digital input and output from the processor, as well as a variable input voltage which is to be measured. Factors which make testing somewhat harder.

Once the board has been assembled, the circuit diagram is shown in Figure 5 and the Veroboard layout in Figure 6, the next stage is to visually check it for solder bridges, etc., and against the circuit diagram. Then, prior to inserting the ICs into their sockets, use a meter to check that there are no short circuits between the power lines and ground. All three voltages from the power supply board are used by this circuit, again before inserting the ICs it is a good idea to connect the circuit up to the power supply and check that the correct voltages are present on the appropriate pins of the IC sockets.

The first step in testing the actual circuit is to ensure that the correct reference voltage is produced for input to pin 9 of the A/D chip. To do this, insert the 741, but not the CA3306, making sure that it is oriented properly and that the power is disconnected whilst doing so. Then, reconnect the power supply and using a meter measure the voltage on pin 9 of the socket for the CA3306. This is the reference voltage and can be adjusted by turning the preset potentiometer. Adjust it until the voltage on pin 9 measures exactly 4.8V.

With the correct reference voltage being produced, we can now insert the CA3306 and test the main circuit. First of all we need to produce a variable input voltage, which we can do by using a 1M ohm potentiometer as a simple voltage divider. Connect one end of the potentiometer track to the +5V supply, the other end to ground and the wiper to the signal input of the circuit. Turn the wiper to the middle before starting testing.

For testing we also need to attach the circuit to the computer's I/O board. The A/D circuit has seven output lines and one input. The output lines carry the digital data for the computer to read and are thus attached to an input port on the I/O board, in this case lines 0 through 6 of port B (line 0 is the least significant bit and line 5 is the most significant, line 6 is the overflow flag). Analogue data is sampled by the circuit when the clock line is toggled and this line is connected to one of the output lines on port C, line 7.

We also need a test program, such as the following short piece of code written in BASIC:

```
 1 REM A/D testing routine
10 BASEADD%=&H300
20 OUT BASEADD%+3,130
30 REM start inputting analogue
   data by toggling clock line
40 OUT BASEADD%+2,0
50 OUT BASEADD%+2,128
60 OUT BASEADD%+2,0
```

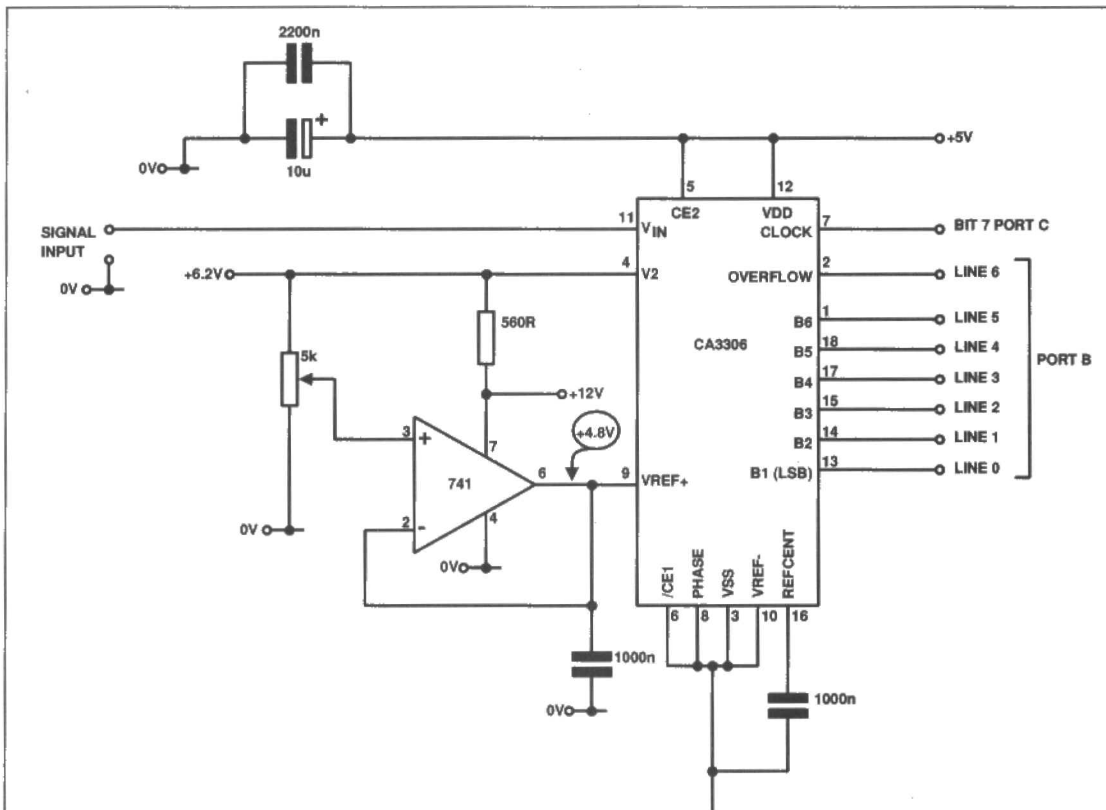


Figure 5. 6-bit A/D converter circuit.

```
70 SENSE% = INP(BASEADD%+1)
80 REM mask out unused input
   lines and overflow
90 SENSE% = SENSE% AND 63
100 REM generate delay between
    each input
110 FOR Q = 1 TO 1000
120 NEXT Q
130 REM print digital value on
    screen
140 PRINT SENSE%
150 GOTO 30
```

When you run this program with the A/D circuit attached and the 1M ohm potentiometer wiper in the middle of its range, the output printed on the screen should be between about 20 and 30. Turning the potentiometer will raise or lower the value.

You may find that the output is very high or very low, in which case first check the voltage on the signal input with a meter. If, with the wiper in the middle position, the input is about +2.5V then you know that the analogue input is correct. Next, recheck the reference voltage on pin 9 of the CA3306, you may need to adjust this slightly. It is also a good idea to use the simple LED logic probe mentioned above to check the state of the overflow line on pin 2 of the CA3306. If this is high (LED lit), then, although the output on the screen may be low, the converter is actually registering a voltage above the reference voltage. In fact, the input voltage range of this circuit is between 0 and about +4.2V with the reference voltage set to +4.8V.

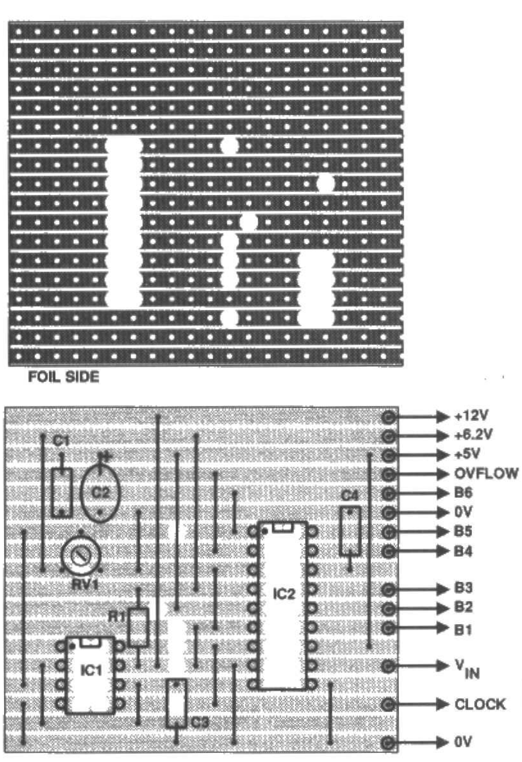


Figure 6. A/D converter veroboard layout

Building the Optical Sensor

This circuit was left till last, because the best way of testing it is to use the A/D circuit. The circuit is shown in Figure 7 and the Veroboard layout for it in Figure 8. Once constructed, it should be visually checked and then checked for power supply shorts, before attaching the input to the signal input of the A/D board, and before applying power.

The MEL12 phototransistor is connected to the board by a short length of two core cable and is positioned in the focal plane of the optical system. As mentioned last month, this is just a box with a single lens, such as that from a hand magnifying glass, the construction is in fact just a simple shutterless camera. On one end, at the lens' focal plane, there is a back board to which the phototransistor is attached. The whole box should be matt black inside to reduce light reflection. The camera unit is then mounted on the stepper motor scanner as mentioned above.

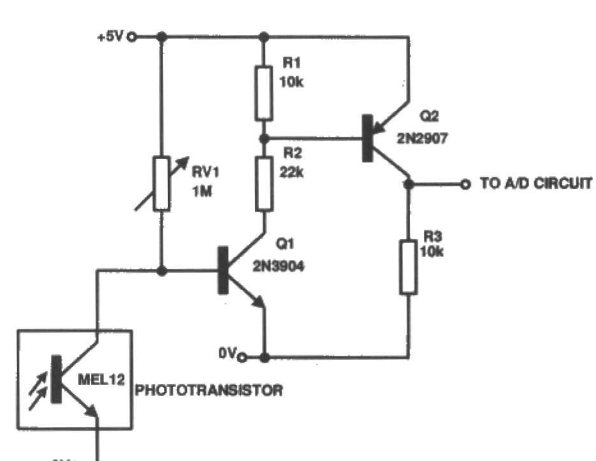


Figure 7. Photo sensor circuit.

The output from the photosensor and signal conditioning circuit is a voltage between about +4.5V and ground. It should be remembered that with no light falling on the sensor, the output is a high voltage and with bright light falling on it, a low voltage. The sensitivity can be altered by adjusting the 1M ohm preset.

With the sensor attached to the A/D circuit, run the above BASIC program and check the output with both no light and bright light. Then adjust the 1M ohm preset until the sensitivity of the system is such that it will register digital values for dark of around 63 and for bright light of about 0. The system should be sufficiently sensitive to register a hand or a sheet of paper passed in front of the lens. If you have problems here, first check the sensor outside the camera, then check that your camera is providing enough light (I used a 2in diameter lens on my final version) and that the sensor is in the focal plane.

Putting the Vision System Together

We now have all the components of a simple robot vision system assembled, tested and attached to the I/O board on a PC. All we need to do now is write a program to use these components to input a simple optical scan of the world around it. The following is such a program:

```
10 REM simple linear image
   scanner
20 REM
30 BASEADD% = &H300
40 OUT BASEADD%+3,130
50 DIM IMAGE% (50)
60 DIM SENSEINPUT% (50)
100 REM main calling loop
    initialistion variables
110 DIRECT = 0
200 REM stepper motor loop
210 FOR MOTORSTEP = 1 TO 30
220 GOSUB 1000
225 IF DIRECT = 2 THEN GOTO 250
230 GOSUB 2000
240 GOSUB 3000
250 NEXT MOTORSTEP
260 DELTIME = 50 270 GOSUB 4000
280 IF DIRECT = 0 THEN PRINT " "
290 IF DIRECT = 0 THEN DIRECT =
2 :GOTO 200
300 IF DIRECT = 2 THEN DIRECT =
    0 :GOTO 200
1000 REM stepper motor control
     routine
1010 OUT BASEADD%+2, 0 + DIRECT
1020 DELTIME = 5
1030 GOSUB 4000
1040 OUT BASEADD%+2, 1 + DIRECT
1050 DELTIME = 5
1060 GOSUB 4000
1999 RETURN
2000 REM photo-sensor input
     routine
2010 TEMP% = 0
2020 FOR TRY = 1 TO 10
2030 OUT BASEADD%+2, DIRECT + 1
2040 OUT BASEADD%+2, DIRECT +
     129
2050 OUT BASEADD%+2, DIRECT + 1
2060 SENSE% = INP(BASEADD%+1)
2070 SENSE% = SENSE% AND 63
2075 REM average out input value
     over ten readings
2080 TEMP% = TEMP% + SENSE%
2090 NEXT TRY
2100 TEMP% = TEMP %/10
2110 SENSEINPUT% (MOTORSTEP) =
     TEMP%
2999 RETURN
3000 REM output print routine
3010 IF TEMP% < 6 THEN GOTO 3200
3020 IF TEMP% < 12 THEN GOTO
     3250
3030 IF TEMP% < 18 THEN GOTO
     3300
3040 IF TEMP% < 24 THEN GOTO
     3350
3050 IF TEMP% < 36 THEN GOTO
     3450
3060 IF TEMP% < 42 THEN GOTO
     3500
3070 IF TEMP% < 48 THEN GOTO
     3550
3080 IF TEMP% < 54 THEN GOTO
     3600
3090 IF TEMP% < 60 THEN GOTO
     3650
3100 IF TEMP% < 64 THEN GOTO
     3700
3200 DOT$ = "0"
3210 GOTO 3800
3250 DOT$ = "1"
3260 GOTO 3800
3300 DOT$ = "2"
3310 GOTO 3800
3350 DOT$ = "3"
3360 GOTO 3800
3400 DOT$ = "4"
3410 GOTO 3800
3450 DOT$ = "5"
3460 GOTO 3800
3500 DOT$ = "6"
3510 GOTO 3800
3550 DOT$ = "7"
3560 GOTO 3800
3600 DOT$ = "8"
3610 GOTO 3800
3650 DOT$ = "9" 3660 GOTO 3800
3700 DOT$ = "*"
3710 GOTO 3800
3800 PRINT DOT$;
3999 RETURN
4000 REM delay generator
     (deltime)
4010 FOR Z = 1 TO DELTIME
4020 FOR X = 1 TO 20
4030 NEXT X
4040 NEXT Z
4050 RETURN
```

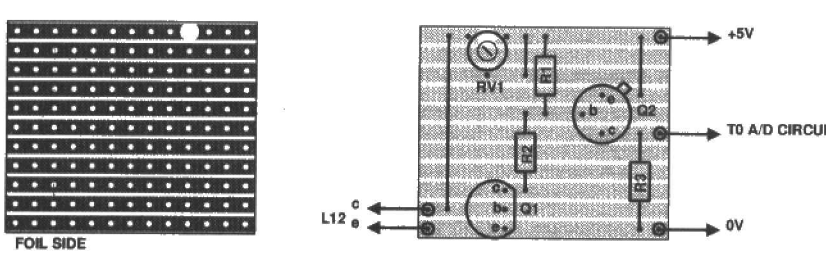


Figure 8. Photosensor veroboard layout.

This has been designed to scan an optical scene and then display on the computer's screen a digital representation of that scene, with very bright areas registering as a 0 or 1 and very dark areas as a * or 9. Thus, a sample scan from this system may look as follows: here one can see that there are two bright areas. One, the first and brightest was in the window and the second less bright was the computer screen and the light coloured wall behind it.

However, although this is a very rudimentary system, it would be sufficient for a mobile robot to locate bright light sources. Or, by looking for significant changes in input values over multiple sweeps, locate a bright moving object within the field of view, an object which once located could be locked on to and followed. These are all functions which can be done by writing the appropriate software.

Further Improvements

```
8789621001579*98*732136899*999
```

With the above system we are only

inputting light intensity data from a single point on the camera's focal plane and by scanning the camera around a scene we are using that single point to build up a light intensity chart for a horizontal slice of the area scanned by the camera. If we want to input a proper image, then we need to use more than one sensor so that we can input several different horizontal slices of the image field. This means that, if we have eight sensors, we can input a digitised image that has a resolution of eight pixels high by thirty pixels wide. Sufficient for very simple image recognition, this will be the subject of the last piece in this series in next month's issue of ETI.

PARTS LIST

Power Supply

C1, 2, 3	100N
C4, 5, 6	1µ TANT
R1, 2, 3	5k CERMET PRESET
IC1, 2, 3	LM317

Motor Control Circuit

C1	100N
R1, 2, 3	10k
R4	100R
R5	220R
IC1	7407
IC2	SAA1027
Stepper Motor	7.5° Step Angle, 8mNm Torque, 130mA Current/Phase

A/D Converter Circuit

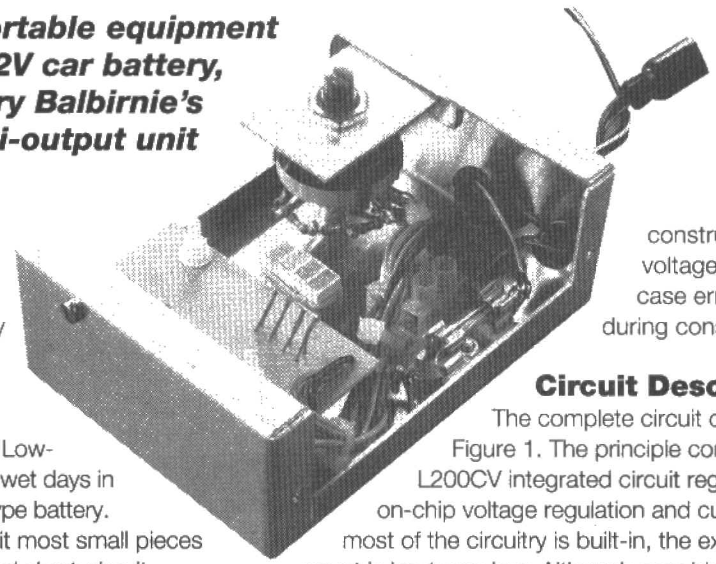
C1	2200N disc
C2	10µ Electrolytic
C3, 4	1000N disc
R1	560R
RV1	5K Cermet preset
IC1	741
IC2	CA3306

A/D Converter Circuit

R1, 3	10K
R2	22K
RV1	1M Cermet preset
Q1	2N3904
Q2	2N2907
Phototransistor	MEL12

Low-Voltage Power Supply

Operate portable equipment from a 12V car battery, with Terry Balbirnie's multi-output unit



This power supply unit has been designed to provide a regulated output of 3V, 4.5V, 6V or 9V using a 12V car battery input. It may therefore be used to operate small pieces of equipment, such as personal stereos, radios and games which would normally use batteries. The Low-Voltage Power Supply will be a boon for wet days in a caravan equipped with a 12V leisure-type battery.

The choice of output voltages will suit most small pieces of equipment. The supply is overload and short-circuit protected with a 250mA current limit, which will be found sufficient for many items including those mentioned above. A personal stereo using a 3V supply typically requires around 150mA and a small radio much less. A well-charged car-type battery could provide such a current for 6 hours per day over several weeks.

The voltage-setting switch is coin-operated, so preventing accidental rotation and children fiddling with possibly disastrous consequences. One of a group of four LEDs on the front panel lights up when the unit is connected to the supply to confirm the selected voltage. This makes incorrect setting less likely. It also serves as a reminder to disconnect the unit after use.

The output characteristics are determined solely by the component values which are fixed in value. However, it is essential to have a multi-tester available at the end of construction to check the voltages and current limit, in case errors have been made during construction.

Circuit Description

The complete circuit diagram is shown in Figure 1. The principle component is IC1 - an L200CV integrated circuit regulator. This provides on-chip voltage regulation and current limiting. Since most of the circuitry is built-in, the external component count is kept very low. Although capable of providing up to 2A, here the IC is used much more conservatively, so the metalwork of the case will provide an adequate heatsink.

The nominal 12V input is applied to pin 1 via fuse FS1. This fuse provides ultimate protection in the event of a short-circuit on the input side. With a supply established, an output voltage appears at pin 5, whose value is accurately determined by the value of resistor R1 and the resistance connected between limiting pin 2 and reference pin 4. In this circuit, R1 is fixed in value and pole A of rotary switch, S1, connects resistors from the series chain, R5 to R7, soldered around the contacts. R3 is always present and this provides 3V when the switch is at its lowest setting. With all resistors connected, 9V is provided. Note that for best accuracy, 1% tolerance resistors should be used as specified in the parts list. It should then be found that all voltages are provided to within 5% of their nominal value.

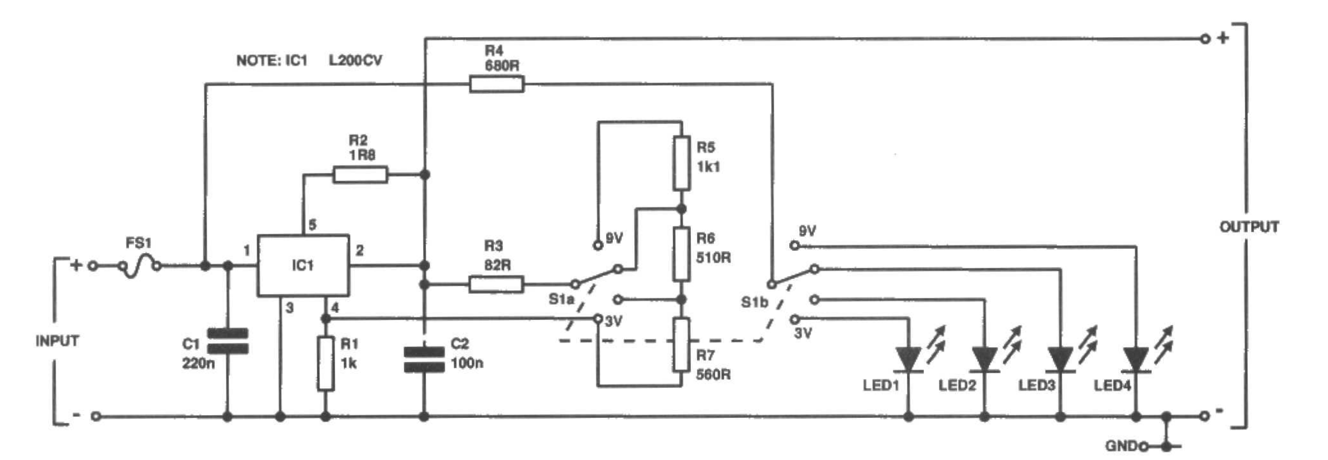


Figure 1. Low-voltage power supply cuircuit.

Resistor R2, connected between IC1 pins 5 and 2, determines the output current limit. With the value stated, this is approximately 250mA. Readers wishing to make changes to the current should choose the resistor according to the formula:

$$R = 450/I$$

Where R is the resistor value and I is the current limit required in milliamps. Note, however, that quite a lot of heat is produced when a low voltage output is combined with a high current requirement. It may therefore be necessary to up-rate the heat sink by using a larger case. Capacitors C1 and C2 are necessary for internal stability of IC1. Light-emitting diodes, LED1 to LED4, which confirm the voltage setting, are switched in sequence by S1 pole B. Resistor R4, is the current-limiting resistor common to all LEDs.

The output is provided by a universal connector which will match most popular types of input socket used on pieces of portable equipment. In some cases, it will be necessary to make up a lead with the appropriate type of plug on the end. The input lead in the prototype consisted of a length of twin wire with a car cigar lighter type plug on the end. Alternatively, a ready-made automotive power lead could be used. This type of connector may be inappropriate in some cases but, again, could be easily changed to suit the application

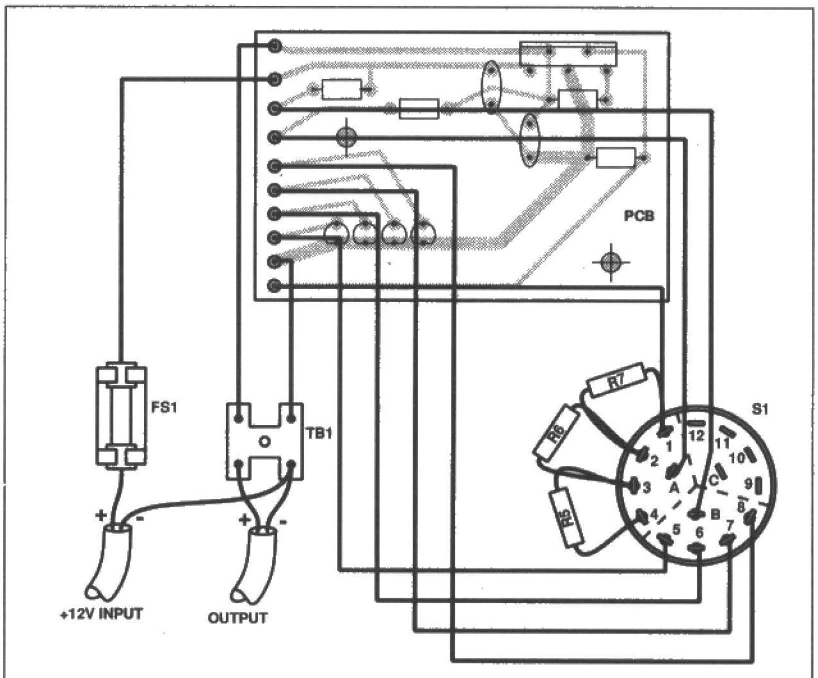


Figure 3. Wiring connections

Construction

The Low-Voltage Power Supply must be built in an aluminium enclosure. A plastic case is unsuitable and should not be used. Note that S1 must be of the 'make before break' type as specified.

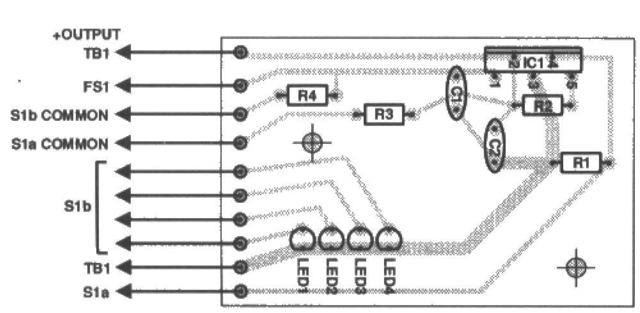


Figure 2a. Low voltage PSU PCB component overlay.

Most of the components are mounted on a single-sided printed circuit board. Figure 2a shows the component side view while Figure 2b shows the underside (copper foil) details. Begin by drilling the two mounting holes in the panel as indicated, then solder the on-board resistors and capacitors in position flat with the board. Add the LEDs (taking care over their polarity or they will not work) and IC1. The tops of the LEDs should stand a few millimetres higher than IC1 tab. Solder 10cm pieces of light-duty stranded connecting wire to the ten points on the PCB. The use of different colours will help in avoiding wiring errors later.

Drill holes in the case for the input and output leads and fit them with rubber grommets. Cut S1 spindle to a length of 4mm and file the end smooth. Using a hacksaw, cut a cross head in the end so that it may be adjusted using a thin coin. Refer to Figure 3 and solder resistors R5 - R7 to tags 1-4 of the switch. Solder the wires leading from the circuit panel to the common contacts of pole A and pole B to tags 1 and 5-8. Tags 9-12 are not connected. Shorten any wires as necessary. It is essential to check carefully that all soldered joints are secure - any loose joint could cause the output voltage to rise, possibly to the full 12V, with consequent ruination of equipment.

Aluminium Panel

Make the aluminium panel as shown in Figure 4 and mount the switch on it. Drill a hole 6mm in diameter in the top of the box so that, with the panel in position, the end of the spindle protrudes slightly through this. Drill two small holes in the case and mount the switch panel temporarily using small nuts and bolts. Make certain that there is no possibility of any tags or components touching the metalwork (which is at supply negative voltage) and causing short-circuits. Check that the adjustment may be made using a coin. Remove the switch panel again.

Cut the hole in the lid for the row of LEDs. Rectangular ones were used in the prototype and these give a good appearance. However, any small LEDs could be used instead. It may help to apply some quick-setting epoxy resin adhesive underneath to bond them all together in line.

The circuit panel is mounted using the two holes already drilled in it and the hole in IC1 tab. Mark the positions of these holes and drill the case to correspond. Attach the circuit panel using thin nylon nuts and bolts and plastic stand-off insulators. The use of nylon fixings will prevent any possibility of short-circuits with the underside tracks. Use a metal nut and bolt to attach IC1. Check that the LEDs take up a position slightly protruding through the hole in the lid of the case. Drill holes to attach the fuse holder and terminal block. Mount the switch panel.

Refer to Figure 3 and complete the point-to-point wiring. Some of the connections are made via the piece of 2A screw terminal block, TB1. Pass the input and output wires through the grommets, leaving some slack on the inside. Tie a knot in each to prevent them pulling free and connect them up as indicated. Insert the fuse into its holder.

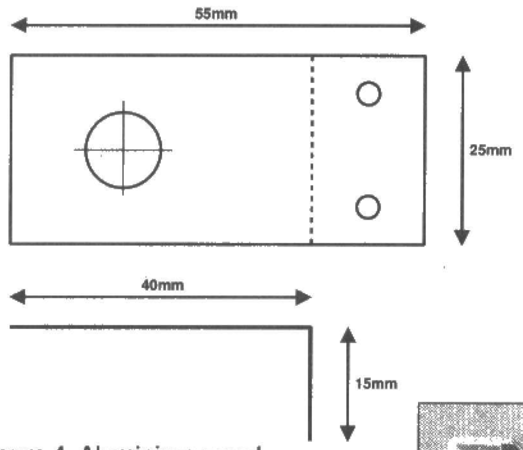
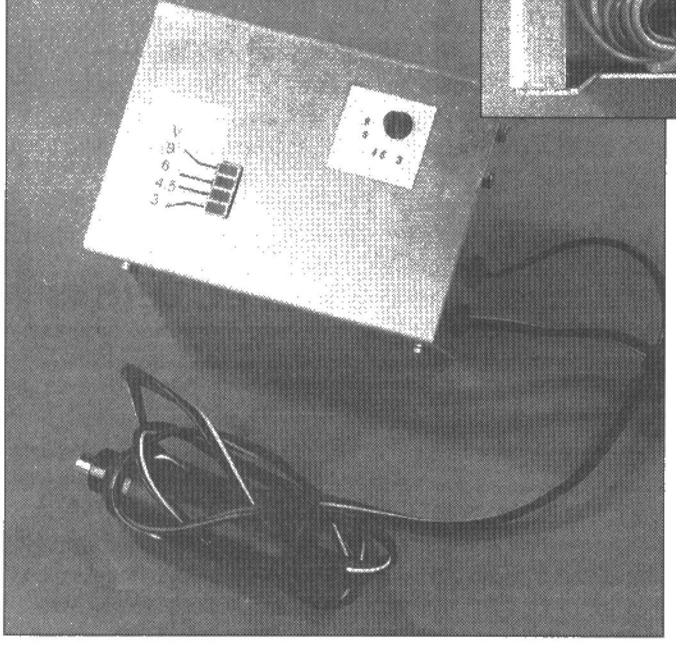


Figure 4. Aluminium panel cutting diagram.

Testing

Use a multitester set to a suitable voltage range and connect it to the output. Connect the input to the 12V supply, observing the polarity. Check the readings on all voltage settings. Next, check the

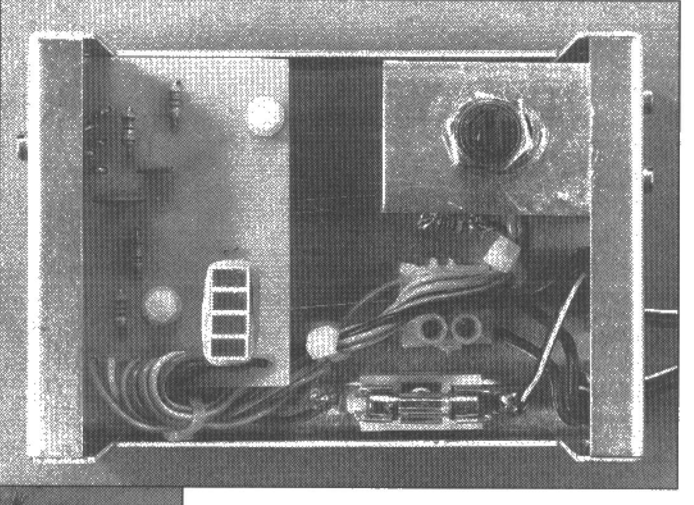


current limit for each voltage setting. To do this, set the meter to a suitable current range covering 250mA. Apply the probes directly to the output and observe the meter reading. Any reading between 200 and 300mA may be regarded as satisfactory. If it is too low, reduce the value of R2 slightly.

Warning

Before using the unit, it is essential to determine the operating voltage of any equipment to be connected. This must never be done by trial and error. The voltage may be marked on the body, but it will also be obvious from the type of battery or batteries used. Where this is a PP3 or PP9 type, the 9V setting is appropriate. However, small pieces of equipment often use individual cells - usually AA size - and 1.5V is needed for each one. For example, a personal stereo normally powered using two AA size cells requires the 3V setting. Using too high a setting - even for an instant - can ruin equipment. Note also that the polarity of the supply must be observed. Although much equipment is protected against accidental reversal of the input, this must never be assumed. Again, incorrect polarity can ruin equipment. The specified type of output lead has an in-line plug and socket which may be used to reverse the polarity as required - make sure this is set correctly.

It will be helpful if the equipment to be connected has a power input socket already fitted and this will be the case with many items. Where no such socket exists, it is often a simple matter to fit one, or to use a set of dummy cells. Where a battery having a snap connector is used, a further similar snap connector may be used 'piggy back' fashion to make the connection.



Note that it is normal for the case to become warm during use - especially around the area of IC1. One final point - when using the Low-Voltage Power Supply, the selector switch should never be rotated while a piece of equipment is connected.

PARTS LIST

Resistors (all 0.25w)

R1	1k0
R2	1R8
R3	82
R4	680
R5	1k1
R6	510
R7	560

All resistors are 0.6W , 1% metal film.

Capacitors

C1	220n ceramic
C2	100n ceramic

Semiconductors

IC1	L200CV voltage and current regulator
LED1-4	red light emitting diodes - see text.

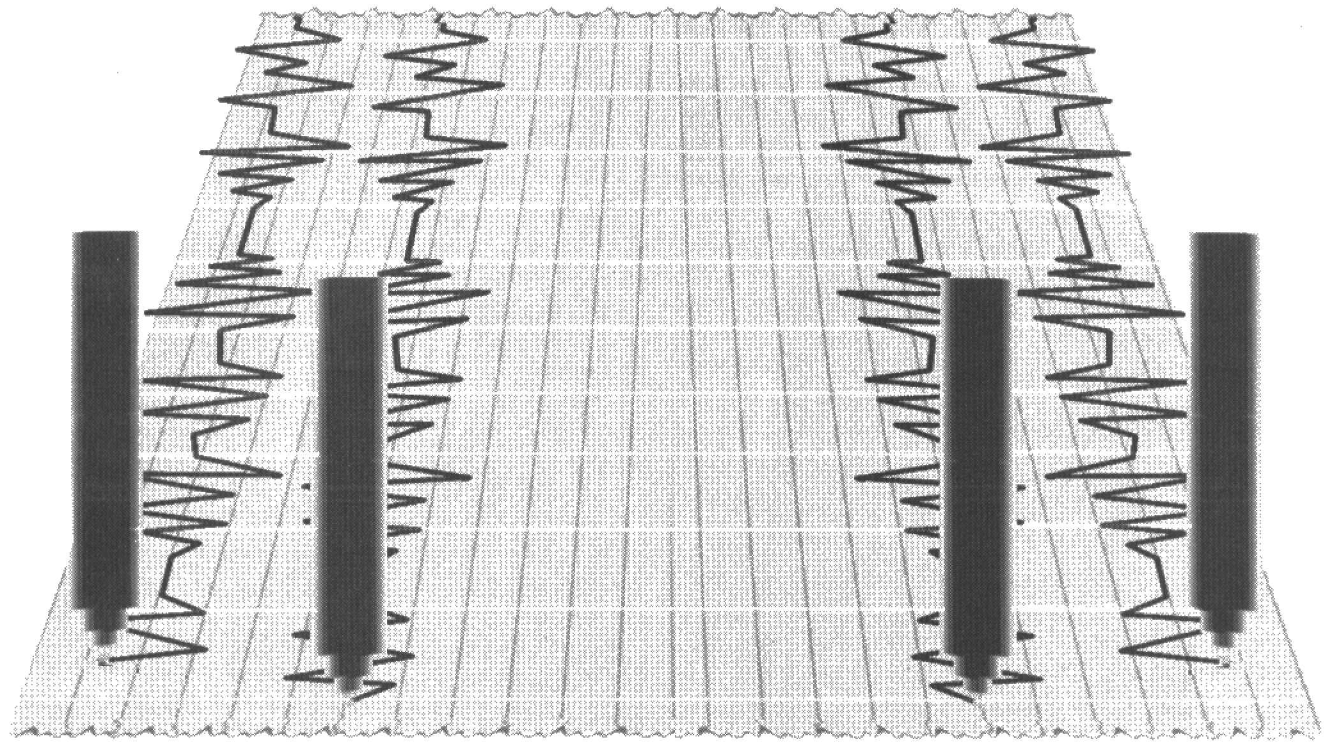
Miscellaneous

S1	3P 4W rotary switch - make-before-break action.
FS1	20mm chassis fuse holder with 500mA fast-blow fuse to fit.

Printed circuit materials, aluminium case size 102 x 70 x 38mm. Automotive cigar plug or ready-made power lead, universal connector or as required, 2A screw terminal block small fixings, aluminium for switch panel, etc.

Buylines

All components for the Low-Voltage Power Supply are readily available and were all obtained from Maplins for the prototype.



A virtual **chart recorder**

With a bit if ingenuity, an old micro can replace an expensive piece of test equipment. Veteran experimenter Keith Garwell shows how it can be done.

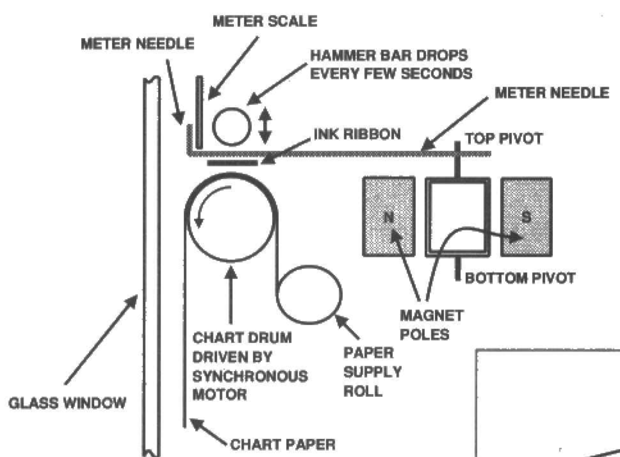


Figure 1. A basic chart recorder mechanism

I have had an ancient Evershed chart recorder sitting on a shelf in the garage for many years. It is one of what I call the 'dotty' recorders, that is the active movement is a 1mA moving coil meter whose needle is thumped every second or so by a bar, so that it strikes the chart paper through an inked ribbon. The result is a tiny black dot on the chart paper. A small synchronous motor drives the paper at a constant speed. Figure 1 suggests the general arrangement in side elevation.

In previous experimental phases, I wanted to record light levels, temperature, etc., for which this single channel Evershed was not suitable. However, a minor mod. consisting of fitting a switch to the bar which thumped the meter needle, plus some electronic switchery driven by a counter, in turn driven by the switch, solved the problem. The recorder now made dots which were controlled by up to four inputs (1mA current inputs). The addition of 4 pots which provided offset currents enabled the position of the four traces to be moved, if required, so that for example the four traces could occupy the whole width of the chart or run side by side, keeping to themselves (see Figure 2).

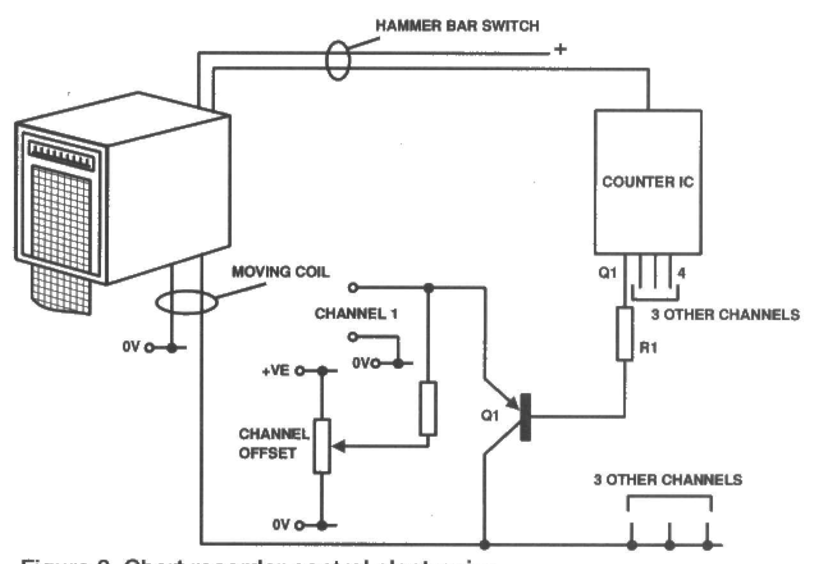


Figure 2. Chart recorder control electronics

More recently, having become very interested in the changes in atmospheric electricity (Reference 1), a chart recorder was required again. Here the Evershed was no good, but let me be quite clear on this. The Evershed is an excellent recorder, it's donkey's years old and still works perfectly. Perhaps what I should have said was that it didn't have the facilities I required.

A look at the catalogues frightened me off. I don't have the sort of money to spend on a hobby (who does?), purely on a device which is probably going to spend 99% of its life on a shelf collecting cobwebs. Not to mention the fact that the paper rolls are frightfully expensive.

What did I want that the Evershed didn't have? Well, for a start, a variable time base, i.e. variable chart speed. The charts are also fairly narrow. Fine for a single trace, but difficult with several traces. The catalogue price was escalating rapidly and an alternative was needed.

The Alternative

Being someone with a long background in computing, the use of a computer seemed to be the logical route to take. I already possessed two or three micros and I have a printer, and printer paper is cheap, at least compared with chart paper. If a recorder could be realised using a computer, the following advantages would be probable.

The chart speed could be varied over a massive range in almost any desired increment, as each step would be governed by an increment which could be as small as milliseconds.

As the operation would be program controlled it would be possible to include arithmetic in the recording process, e.g. it could record the square root of the input, if that was what was required.

Either tape or disks would be available for recording data, a very cheap and convenient arrangement.

The data would also be shown on a screen and this would make it possible to be selective, saving or printing only the interesting bits.

There is no constraint on the way in which the charts can be printed. It would be possible to print across the width of the paper, along its length or in any other way appropriate to the problem in hand.

Certainly in my case it would be cheaper, as I already had the machine(s). However, it might be cheaper in any case, especially when considering the machine could have other uses.

A Closer Look

Let's go back to Figure 1 for a moment, just to note the essential components.

Firstly, a rotating chart drum, usually with teeth at either end which engage in holes along the edge of the paper chart, similar to 35mm film but wider. The drum diameter and the speed of rotation are both chosen to give so many inches (or more likely nowadays, millimetres) of paper movement per hour. For example, on my Evershed the chart speed is half-an-inch per hour and the paper is 2in wide inside the perforations, 2 1/2in overall. The paper motion therefore represents the time-base. In effect the X axis.

The Y axis is given by the movement of the meter needle across the width of the paper. The position of the meter needle is recorded by a series of dots which are so close together that a solid line is drawn. Again, the meter sensitivity is chosen to match the paper width to a given current, in this case 1mA gives 2in of movement, and the paper chart is marked with reference lines which indicate the current on a scale of 0 to 10 and time in hours, 0 to 23.

To use any computer as a chart recorder, therefore, we must have the corresponding items. A means of digitising current or voltage, of measuring time and a means to observe the result.

My Method

I will first sketch out the way in which I use a Dragon micro as a chart recorder, to give a feel for what is possible and then later in the article go into the details, including the electronics, as well as generating software outlines and suchlike, which can be adjusted to suit more or less any machine.

First an outline of the Dragon itself. It came out at about the same time as the BBC machine and it has four analogue inputs of 0 to 5V. The digitiser is six bit, giving a scale of 64, i.e. 0 to 63.

On the face of it that sounds quite low, especially as there are plenty of eight and twelve bit digitisers around, but in point of fact, I have never found this a shortcoming, as it still gives sufficient accuracy. Remember that a moving coil meter, unless it's a very superior one with a knife edge needle and a mirror behind, it will only resolve about one part in a hundred. So it is quite as good as the recorder it replaces.

The Dragon has quite a good graphics screen for its time and price. 256 pixels wide and 192 pixels deep. This conveniently allows a display of three sets of traces drawn horizontally one below the other. According to my arithmetic, 3 x 64 is 192 - I'm sure that is not a coincidence!

256 pixels horizontally means it can have 256 steps. So, for example, as I'm currently using it, a step every 2 seconds gives a screen width of 512 seconds, or just over eight and a half minutes. This works out as 25 1/2 minutes for a screenfull. A cursor 64 pixels high indicates the current position and steps along at each tick of the time-base, leaving the current values behind it as it moves. As well as drawing the traces on the screen, the data is also saved in Dragon memory and can therefore be saved permanently, but more of that later.

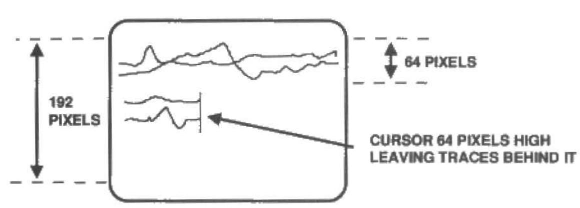


Figure 3. Display of a screen based chart recorder

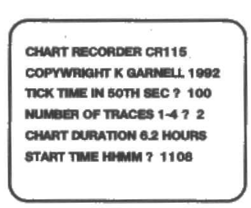


Figure4. Power up screen for virtual chart recorder

When the traces get to the bottom of the screen, they start again at the top left hand corner, so there is always the last 25 1/2 minutes showing. Figure 3 will hopefully clarify the display.

Figure 4 shows the text screen when the recorder (sorry, micro) is first powered up with this program. The Dragon is rather limited with text, as it only allows for 16 lines of 32 upper case characters. Remember this is driving a TV, not a monitor. Although it will also drive a monitor, there is no provision for changing the text screen, as there is on the Beeb.

At the top of the screen is the heading. In this case, CHART RECORDER CR115 and below it the copyright announcement. Whether you put the copyright announcement on or not is up to personal preference - I always believe in doing it. One never

knows when something might turn out to have real commercial interest and if copyright is declared, then there's much less argument if you want to charge real money for it.

The top line perhaps sounds like a trimming, but in practice I've found it a very wise thing to do, because I find it very easy to forget what a program is for and how it works. Also, in this case, we may have more than one chart recorder, since with a programmable device it is so easy to change its scope. For instance, as already suggested, arithmetic can be included. I therefore make notes about each version of a program so that in six months time I can find out what it's all about.

The next line asks for the tick time. In the case of the Dragon, the internal timer ticks at 50ths of a second and this is a convenient unit to give the time in. In the case of 2 seconds, this figure is 100 as shown in Figure 4.

The next question asks for the number of traces and, again in the case of the Dragon, there are only 4 inputs (we will talk about more inputs later) so this is the only option. The reply 2 in Figure 4 is taken from a real case, the more or less gently sloping trace being light intensity and the wriggly one atmospheric current, -1nA to +1nA.

At this point the program does some arithmetic and comes back with a figure of 6.2 hours as the longest time the system can be left running without losing data. After 6.2 hours, the information will have reached the limit of available memory and data storage will start again at the beginning in a similar fashion to the way the traces are drawn on the screen. In the same way, a marker is put into memory to indicate the current position. Usually, the data would be saved before the 6.2 hours was up.

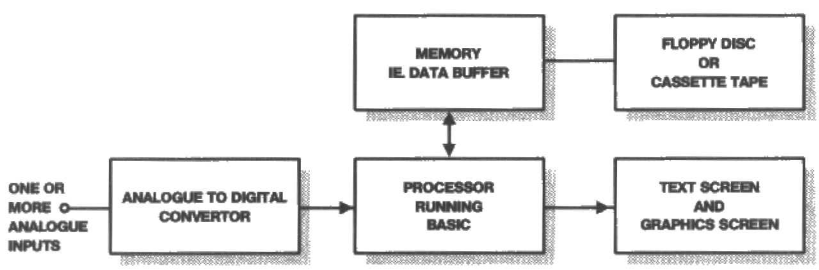


Figure 5. Block diargram of virtual chart recorder

The final question asks for the start time in hours and minutes. Again, for what I do, this has so far been close enough (remember that as it's digital, there could be a discrepancy of up to a minute). There is no reason why it shouldn't be hours, minutes and seconds if required. That figure is saved along with the rest of the data in memory and so is the number of traces.

Of course changing the step-time and/or the number of traces, changes this duration. If the step time was 500 (ten second steps) then the chart time would be something more than 30 hours, a useful figure for a day's recording, leaving plenty of latitude for the time at which the data has to be 'collected'.

All these figures will depend on the computer system being used, but again, more of that later.

Necessary Hardware

Now that we have some idea of what is possible and how it might look, we are in a position to decide what hardware will be needed.

To some, the next bit will be stating the obvious, but to others new to computing it may be helpful. Figure 5 shows the major items. A processor running BASIC, memory, some form of magnetic storage (either floppy disk or magnetic tape), a screen so that we can see what is happening and finally, an analogue to digital converter.

All machines will provide memory and processor. The screen can be either a TV or monitor. Here, the bias must be in favour of a monitor, as the definition will be better than that of a TV, which is always an advantage when drawing graphs of any sort. Note that I'm saying 'biased in favour', rather than essential. A graphic screen capability is essential to draw the traces, but it doesn't have to be very high definition. My system is only 256 by 192 pixels.

My system has 32Kb of memory which is just a bit limiting, 64Kb would be much better. Remember that both the program and data have to co-exist in memory. The type of processor is not very important, and early 8 bit machines are fast enough. By default, all machines will have either floppy or tape, as apart from anything, else the program must go somewhere!

This leaves the most important bit till last, the analogue to digital converter, or ADC as it is more commonly abbreviated to. Some machines have them and some don't. Among the haves are the Dragon and the Beeb (BBC B machine). However there are many have nots, the IBM PC and its look-alikes (clones if you prefer it) and, as far as I recall, both the Amiga and Atari and various Amstrad machines.

However, if you possess a have not, don't despair because a look through the appropriate magazines will almost certainly uncover the existence of ADC adaptors or add on I/O ports which can be used to drive an ADC. They exist as auxiliary boards for the PC to go in a spare slot, or as adaptors to fit the printer output port or serial port for others. Adaptors which plug into a machine highway exist for Amstrads, Sinclairs and some others.

If money is really short and you already have a machine with an RS232 (serial) port, there is another alternative, which is to provide an ADC via the serial highway of the machine, providing it will run at 2400Baud, no parity, 8 data bits and 1 stop bit (see Reference 2). This article covers the subject of driving external devices in general via the serial port.

To sum up, the hardware needed is -

Either -

A machine with ADC already built in plus graphic ability.

Or -

A PC or other machine with - At least 32K of memory, preferably 64K or more. A graphic capability of at least 256 by 192. An ADC adaptor via serial port or other means. A serial port, if it is to communicate with another machine.

A Fundamental Decision

Before deciding what to do in the way of employing a machine you already own or intend to buy, there is one decision to make.

It is important to bear in mind the way in which a chart recorder is used. Unless we are talking about a full time laboratory, for the average experimenter or project man, a chart recorder will most likely spend a lot of time on the shelf collecting dust. When it is used, however, it is usually in a 24 hour mode, being used continuously to observe some phenomenon over maybe a quite long period of time.

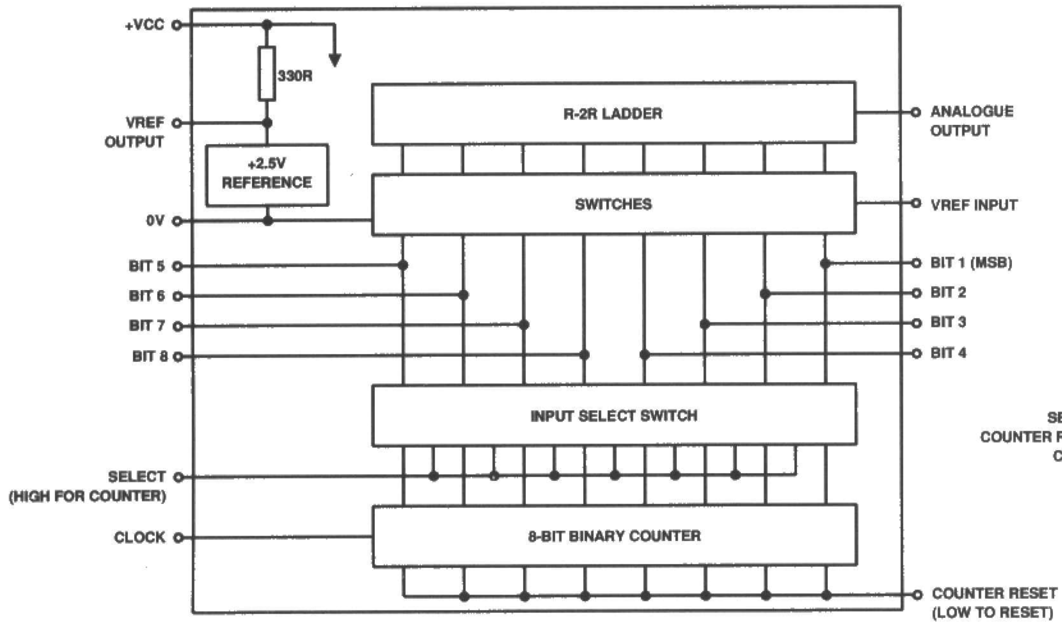


Figure 6(a). Block diagram ZN 425E

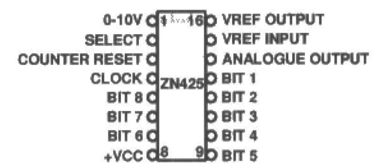


Figure 6(b). ZN 425E pin out

If you are contemplating an existing machine, one that you already own, then can you do without it for the sort of time you might be using it as a chart recorder? As an illustration, taking my case, the answer is quite simply no. The PC which I normally use, is used for all sorts of things, including ETI articles and I couldn't possibly dedicate it to chart recording. I therefore have a separate machine which I use as the chart recorder and whenever necessary, because of the limited memory, I transfer the data to the PC via a serial link. The transfer time is quite short so that is of no consequence, the data being saved directly onto floppy disk.

This is undoubtedly the most convenient arrangement, especially as I already had both machines anyway. On the face of it, it sounds an expensive solution to the problem but in fact it's not as bad as it might seem. The PC is a straightforward twin floppy, monochrome device, the bottom end of the range and the other processor is my old friend the Dragon. Both of these machines are available cheaply on the second hand market, especially with all these fancy gadgets coming along, like Windows and 486 processors. The poor old monochrome floppy engine then gets left to gather dust and is well worth £100 of anyone's money, providing it's in reasonable condition and has the graphics capability.

As well as advertisements in ETI, it is well worth getting one of the general computer magazines, because companies do advertise these machines both second-hand and new, at very reasonable prices. It should be possible to buy a PC and a new ADC adaptor to fit the serial port all for less than £200, or very little more, but don't forget the graphics requirement.

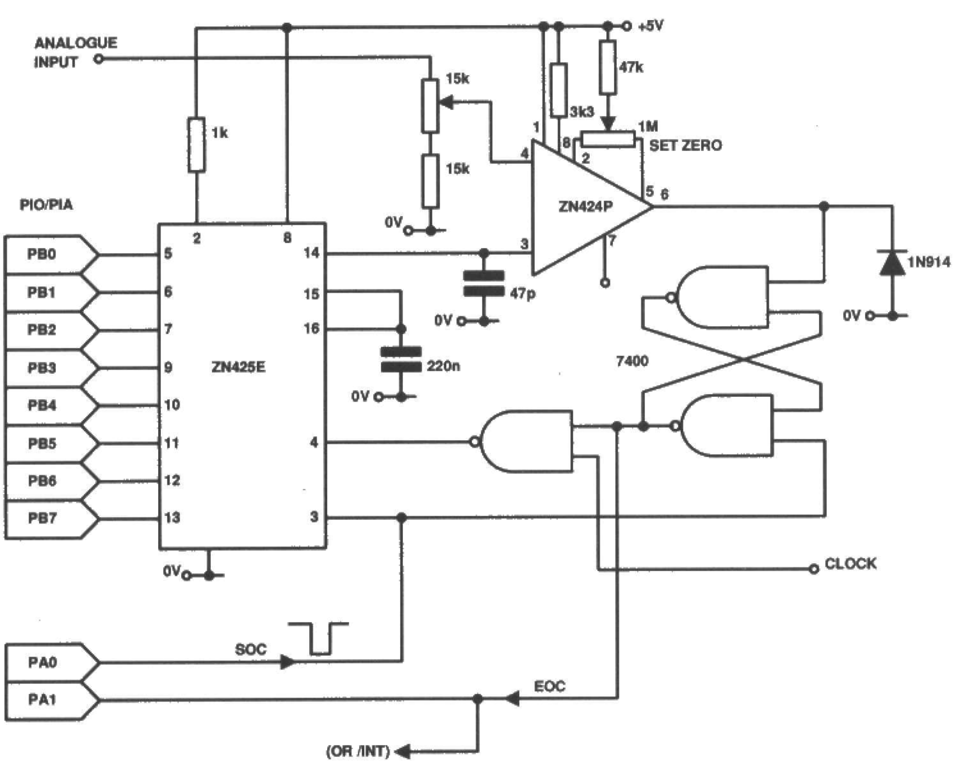


Figure 6(c) A/D converter ciruit using ZN 425E

Implementation

The ADCs

The first thing I'm going to consider is the ADC, as after all, that is the crunch point of the whole affair. I shall consider both

the hardware and the software for the ADC and then the software for the rest of the recorder. I shall give the software in BASIC - this is almost universal these days and it should be quite easy to make any changes required by older machines, perhaps with the exception of the Beeb as they use a completely non standard BASIC. However, if the Beeb is your favourite machine, you will know its language sufficiently well to do the necessary translations.

Built in ADCs

A word about machines with a built in ADC system. The Dragon which I use is fairly representative and the Beeb is similar. I shall assume that the ADC software sub-routine starts at line 200. If we make this the case, then the rest of the software will be interchangeable between many machines.

As an aside, it is good practice with BASIC to put the much used routines early on in the code. This is because whenever there is a change of line number, e.g. in a gosub, the BASIC interpreter will start at the first line and scan through the program until it finds the specified line. Consequently, I write so that lines 10-90 cover setting up procedures, lines 100 to 999 contain subroutines and then line 1000 onwards contains the main code.

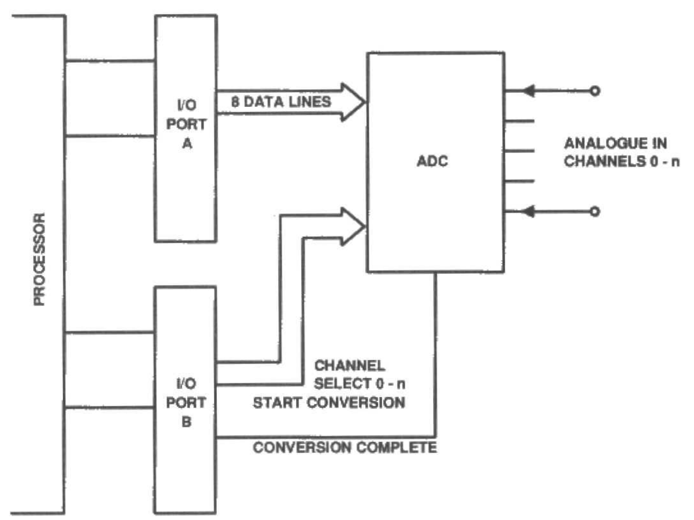


Figure 7. Block diagram of multi channel analog to digital converter circuit

Returning to the Dragon, 4 ADCs are connected to the joystick ports as the Dragon caters for analogue joysticks. They appear as an array called JOYSTK(), thus JOYSTK(0) refers to the first one and JOYSTK(3) refers to the fourth. In the setting up procedures, an array will be declared called AV(3) (the Dragon only recognises the first two characters of a variable name, so I use AV for ADC-value) so the code is very simple and, laid out one statement, per line becomes -

```
200 FOR I=0 to 3
210 AV(I)=JOYSTK(I)
220 NEXT
230 RETURN
```

Thus, each time a GOSUB 200 is performed, the ADC values will be read into the AV() array.

One thing I should mention follows on from the way in which BASIC accesses the lines of code. If time is very important, e.g. more than one or two samples per second are required, it helps tremendously to pack several statements onto each line. I have put the above on four lines so that the steps are clearer, but in fact it is better to put it on one line.

Don't go too far in this direction otherwise the lines will become difficult to read. Use your own judgement and remember that a statement per line will always work. The chart recorder program is not so long that it is unreasonable to get it working with the statement per line approach and then use longer lines after it is all working, to get the program to run faster.

For the BBC machine, the code is very similar, the JOYSTK() keyword being replaced with ADVAL(...). However, there is one little complication. In the case of the Beeb, it is necessary to wait for the conversion and the code thus becomes-

```
200 FOR I=0 TO 3
210 IF ADVAL(0) DIV 256I THEN 210
220 AV(I)=ADVAL(I)
230 NEXT
240 RETURN
```

Now how about one line for that? Be careful that you don't change the logic!

ADCs as an Add-On

Using the printer port or an I/O port.

If one ADC is sufficient, your machine has a printer port and you can access the PAPER OUT line, then there is a very simple and cheap solution. Figure 6 shows the circuit.

The ZN425 costs about £5 and is readily available from component suppliers, as is the CA3140 op-amp (around 50p) and the Centronics 36 way socket (around £2). The only other item required (apart maybe from a box to put it in) is a 5V power supply. As the devices in Figure 5 only take a few milliamps, a suitable power supply can be made up from a little 6V mains transformer, rectifiers, a bit of C and a 100mA 5V regulator (78L05).

The ZN425 is actually a DAC, so connecting it to the 8 output lines of a printer port allows the generation of any voltage between 0 and 2.55, by sending the appropriate character to the printer. Using something like LPRINT CHR$(n), where n is the corresponding number 0 to 255, does the trick.

To use it as an ADC, all that's needed is the addition of a comparator, to compare the incoming analogue voltage with the output of the DAC. Since, the printer port is primarily an output there has to be some means of checking the result of the comparison. This is where the PAPER OUT line comes in, as it is an input line from the printer.

Assuming a printer port fitted with a cable and standard Centronics printer plug, then Figure 6 shows the connections. Pins 2-9 on the Centronics socket (data bits 1-8) go to 5-7 and 9-13 on the ZN425. Here, a word of warning. It is common practice on DACs and suchlike for the most significant bit to be called data bit 0 or 1 and the least significant bit to be called 7 or 8.

Pin 14, the analogue output of the DAC, goes to the positive input (3) of the op-amp and the actual analogue input to be measured, to the negative input (2). There is no feedback in this case, as the op-amp is being used as a comparator, so the output from pin 6 goes to the PAPER OUT error pin on the Centronics socket.

In operation, the PAPER OUT error shows whether the input is higher or lower than the output of the DAC and consequently the output from the printer port. Remember that the measurable

input voltage is in the range 0 to 2.55V. If the input voltage may be outside these limits accidentally, then put a 1MR resistor in series with the input to pin 2 of the op-amp.

Now how do we drive it, software wise? Well there are two answers to this question, the long easy way and the fast complicated way. The long easy way is to provide (starting at line 200) a FOR loop, which starts with I=0 and goes up to I=255. During this loop, look for a change in the PAPER OUT signal. Stopping the loop at this point will give the value of the input.

As I don't know what machine you will be using, I can't give the code to check for the PO error so I will assume PAPEROUT is a variable which is true or false, depending on the state of pin 12 of the Centronics socket.

The long easy way goes like this

```
200 FOR I=0 TO 255
210 LPRINT CHR$(I);
220 IF PAPEROUT THEN ADCVAL=I:I=256
230 NEXT
240 RETURN
```

Setting I=256 is a much better way of forcing an exit from a FOR loop than using a goto, e.g. in this case GOTO 240.

On return from the subroutine, the variable ADCVAL will be just that, the value of the input. At the end of this section, I will give a little program suitable for testing the system.

Well, what can go wrong? Not much. If it doesn't work properly, then check -

That you have got the semi-colon after the lprint statement. If you haven't, the printer driver will send carriage-return and line-feed after each statement and as these have values of 10 and 13, it will muck up the system.

It may be that the sense of the PAPEROUT variable is inverted, try changing line 220 to -

```
220 IF PAPEROUT=0 THEN ADCVAL=I:I=256
```

An alternative to the printer port is to use 8 bits from an output port (there are adaptors for most machines) and 1 bit to an input port for the output of the CA3140.

And now, if connected to I/O ports, let's assume they are output port number OUTPORTNUM and input port INPORTNUM.

The previous code now becomes -

```
200 FOR I=0 TO 255
210 OUT OUTPORTNUM,I
220 IF INP(INPORTNUM) THEN ADCVAL=I:I=256
230 NEXT
240 RETURN
```

If this doesn't work, then the checks are as in the previous case, but there is an extra possibility, namely that more than the one bit is appearing in the input port. Suppose bit 0 of the input port is connected to the op-amp, then change line 220 to -

```
220 IF INP(INPORTNUM) AND &H01 THEN
    ADCVAL=I:I=256
```

ANDing the portvalue in this way will ensure that only bit 0 is looked at. Of course, if it's any other bit, change the &H01 to correspond.

An ADC Test Program

The following program is suitable for testing all of the systems given in this article, assuming that the appropriate routine starts at line 200 onwards.

Any setting up that may be necessary, e.g.

```
20 DEFINT A-Z
90 GOTO 1000
200 and onwards, the digitise routine
1000 Any further setting up, e.g. set up
     I/O ports and clear the screen
1090 PRINT"R=run continuous, Q=quit, any
     other key for single shot"
1100 LOCATE 14,1
1110 GOSUB 200
1120 PRINT ADCVAL;"     ";
1130 IF CK$="r" THEN IC$=INKEY$ ELSE
IC$=INKEY$:IF IC$="" THEN 1130
1140 IF IC$"" THEN CK$=IC$
1150 IF CK$="r" THEN 1100
1160 IF CK$"q" THEN 1100
```

The Fast, Complicated Way.

You will doubtless appreciate the fact that the higher the input value the longer it takes for the routine to find the matching value. So, using the previous routines will give the value fairly quickly if it is small, but will take much longer if the value is large. Apart from limiting the speed at which points can be plotted by our chart recorder to be, the fact that the speed is variable between wide limits (255 to 1 in the worst case) makes the timing more difficult, because our recorder has got to have a clock in it somewhere.

And so we come to the fast, complicated way. The technique is known as successive approximation and goes like this. Send a mid range value (128) and see if the value to be measured is greater or less than the input. If less than, repeat with the middle again, this time 64. If higher, again use the mid value obtained by adding the 64 to the 128.

One of the complications comes from the fact that we can only ask higher or lower, there is no means of checking equal to. However this can be allowed for at the end of the cycle by an 8th step which will either add one or leave it as it is.

Now, using some of the previous code to help comparison, here's the new code -

In the setting up declare an array called DIFFVAL(8) and set its values to

```
128, 64, 32, ..... 1, 1.DIFFVAL(0)=128:.......:
     DIFFVAL(7)=1:DIFFVAL(8)=1
200 ADCVAL=DIFFVAL(0)
210 FOR I=1 TO 8
220 LPRINT CHR$(I);
230 IF PAPEROUT=0 THEN
    ADCVAL=ADCVAL+DIFFVAL(I):GOTO 250
240 IF I<8 THEN ADCVAL=ADCVAL-DIFFVAL(I) 250 NEXT
260 ADCVAL=ADCVAL-1
270 RETURN
```

The terrific advantage of this routine is that it only ever takes 8 steps and always takes 8 steps. Since the average for the earlier method would be 128 steps, this system is 16 times faster.

The IBM PC (or Compatible) and the Single Input ADC

If you are using a PC then the problem of sending a value to the printer and gaining access to the PAPER-OUT error becomes very straightforward, although perhaps it is uncertain ground to those who have not used software interrupts so a quick word is

not out of place.

The disk operating system, usually abbreviated to DOS, as supplied with the PC (MS DOS) has dozens and dozens of useful subroutines built in and available to the user. These can be accessed by loading certain control numbers into the machine registers and then performing an interrupt function. This causes the subroutine to be performed and when finished, it returns to the user with the results, if appropriate, in one or more of the registers.

In fact, there is just what we need in the PC DOS. Interrupt number 17 (all numbers in hexadecimal) sends to the printer specified in register DX the value in register AX. When finished, the top 8 bits of register AX contains the printer status, which includes the PAPER_OUT error.

I will include here the code written in BASIC, which will test the circuit of Figure 6 with all the trimmings. The lines of code will be numbered, but I will insert in between general comments which are not numbered and are not included in the program.

The general arrangement is that a buffer is set aside in memory for the code which calls the printer interrupt and later on it will contain, in addition, the chart data.

BASIC does not usually give a means of generating an interrupt,so we will have to use machine code. We know there will be a buffer for the data, so the machine code may as well go into it at the beginning. Don't forget to set the buffer pointer above the machine code when we come to it, otherwise the data will overwrite it.

```
10 DATA ADC for PC using SUCCESSIVE APPROXIMATION
   V1.05(Yes, it took 5 tries to get it right!)
12 DATA Copyright K. Garwell 1993
   Available to all readers of this magazine.
   Now the real stuff. All variables declared as
   integer.
15 DEFINT A-Z
20 DATA
18,B8,OO,OO,2E,A0,00,00,BA,00,00,CD,17,2E,88,26,0
1,00,CB,90
```

The machine code for the interrupt - will be loaded into the buffer shortly.

Next define the segment address of the buffer this is appropriate to a 640Kb machine and is the start of the last 64K.

```
30 DEF SEG=&H9000
40 DIM DIFFVAL(8)
50 DIFFVAL(0)=&H80:DIFFVAL(1)=&H40:DIFFVAL
   (2)=&H20:DIFFVAL(3)=&H10
60 DIFFVAL(4)=8:DIFFVAL(5)=4:DIFFVAL(6)
   =2:DIFFVAL(7)=1:DIFFVAL(8)=1
90 GOTO 1000

200 ADCVAL=DIFFVAL(0)
210 FOR I=1 TO 8
```

Put the ADC value into the first byte of the buffer. Status appears in the second byte.

```
220 POKE 0,ADCVAL
230 CALL CODESTART:CALL CODESTART:STATUS=PEEK
    (1)AND &H20
```

The printer routine is called twice to give the CA3140 time to settle. Remember the machine code is much faster.

```
240 IF STATUS=0 THEN
    ADCVAL=ADCVAL+DIFFVAL(I):GOTO 260
250 IF I<8 THEN ADCVAL=ADCVAL-DIFFVAL(I)
260 NEXT:ADCVAL=ADCVAL-1
270 RETURN

1000 BUFFER=0
1010 CODESTART=BUFFER+2
1040 CLS:LOCATE 8,1:READ IC$:PRINT IC$:READ
     IC$:PRINT IC$:LOCATE 12,1
```

Copy the machine code into the buffer starting at 3rd byte. First byte of data gives the number of bytes to be copied.

```
1050 READ NUMBYTES:FOR I=BUFFER+2 TO
     BUFFER+NUMBYTES+2
1060 READ
     BYTEVAL$:BYTEVAL=VAL("&H"+BYTEVAL$):POKE
     I,BYTEVAL
1070 NEXT
```

Put up the program options

```
1080 PRINT"R=run continuous, Q=quit, any other
     key for single shot"
```

And start the test loop.

```
1100 LOCATE 14,1
1110 GOSUB 200
1120 PRINT ADCVAL;"     "
1130 IF CK$="r" THEN IC$=INKEY$ ELSE
     IC$=INKEY$:IF IC$="" THEN 1130
1140 IF IC$<>"" THEN CK$=IC$
1150 IF CK$="r" THEN 1100
1160 IF CK$<>"q" THEN 1110
```

Multiple Input ADC

As DIY

For the DIY enthusiast, there are ADC chips available with the means of measuring more than one input. Any of these will require at least the following lines-

8 output lines from the ADC for the conversion data.
2 or more input lines to select the required input.
1 line input to the ADC to say perform conversion.
1 line output from the ADC to say conversion complete.

This all tots up to 9 data lines into the processor and 3 or 4 lines out to the ADC, which amounts to a requirement to add on to your machine an I/O adaptor for two 8 bit ports, at least one of which can be set up individually for input or output.

There we have a nice little design exercise with which I can't provide much help, as I have no idea what equipment you will use. Figure 7 gives a general idea of what it might look like and I shall be able to talk about the software later.

Multiple Input Via RS232, The Easy Way.

Here I am going to suggest that you actually pay real money for a complete, ready built unit. Don't panic. The unit is around £100 (Reference 3, and see also advertisements in copies of ETI) and if you already have a suitable machine (RS232 at 9600Bd and a standard interface) it represents a good buy, especially if its a chart recorder you want and not the hardware exercise!

The unit in question (Pico Technology ADC-16) requires no power supply (it gets all its power via the RS232 interface), has 8 inputs and a resolution of 8-16 bits. Furthermore, it gives the sign of the input, either positive or negative.

The modus operandi is very simple. When a sample is required, a byte of control information is sent to the device, giving the resolution and channel number and in return the device sends the result of digitisation in 3 bytes. Although initially designed for the PC, it can be driven via the serial interface without reference to the machine type, provided that the BASIC used has the commands and the machine has the correct lines, which we will see in a moment.

The connections for the standard 25 way D type are straightforward, viz. -

ADC	Machine	Line
2	2	Transmit
3	3	Receive
20	4	RTS
7	7	Common gnd
4	20	DTR

The ADC is female, while the processor is male. Don't miss the crossover between 4 and 20 (this should not be made if the ADC-16 is used with its supplied software).

Some machines have a 9 pin or other connector and it is best to check with the handbook to see which line is which. Again, a cross will have to go in between RTS and DTR.

Now lets have a look at the software to test such a rig. To keep life simple, I will repeat the test program but without the complication of the buffer. There is no need for any machine code with this rig.

```
10 DATA ADC-16 Test driver V1.00
12 DATA Copyright K. Garwell 1993
```

Still free to readers! The only setting up is done when the file is opened (see below).

```
90 GOTO 1000
```

Don't be mislead, the print command is addressing a file not a printer. The channel, resolution, etc., is built into the control byte. Send the control byte

```
200 PRINT #1,CHR$(CTRLBYTE);
```

Wait for a reply

```
220 IF LOF(1)<0 THEN 220
```

Read the three bytes

```
230 ADC$=INPUT$(3,#1)
```

Convert them to an integer including sign

```
240 ADCVAL=ASC(MID$(ADC$,2,1))*256+ASC(MID$
    (ADC$,3,1))
250 IF ASC(ADC$)=&H2D THEN ADCVAL=-ADCVAL
```

And bingo

```
260 RETURN
```

```
1000 CLS:LOCATE 8,1:READ IC$:PRINT IC$:READ
     IC$:PRINT IC$:LOCATE 12,1
```

Put up a heading, read channel, etc.

```
1010 INPUT"Channel number";CHAN
1020 INPUT"Resolution";RES
1030 INPUT"Single ended differential";IC$
1040 IF IC$="d" THEN MODE=0 ELSE MODE=1
1080 PRINT"R=run continuous, Q=quit, any other
     key for single shot"
```

Construct the control byte, bits 7-5 chan, 4-1 res, 0 is mode.

```
1090 CTRLBYTE=(CHAN-1)*32+(RES-1)*2+MODE
```

Now the all important command to set up the RS232 port. 9600 baud, no parity, 8 bits, 1 stop bit, set the lines to give the required pos. and neg. supply.

```
1100 OPEN"COM1:9600,n,8,1,RS,CS,DS,CD" AS #1
```

And away we go as before.

```
1200 LOCATE 17,1
1210 GOSUB 200
1220 PRINT ADCVAL;"     "
1230 IF CK$="r" THEN IC$=INKEY$ ELSE
     IC$=INKEY$:IF IC$="" THEN 1230
1240 IF IC$<>"" THEN CK$=IC$
1250 IF CK$="r" THEN 1200
1260 IF CK$<>"q" THEN 1210
1270 CLOSE
```

If you have neither ADC nor machine, the combination of IBM PC (or its look-alike) and one of the Pico models (Reference 3) looks to be one of the best buys. I admit that we are now talking money, but it should be possible to pick up a second-hand PC for little more than £100.

From time to time, companies update their equipment and old PCs are left to collect dust. These are well worth having, especially for a dedicated chart recorder. The prices for new PC compatibles cover a wide range and can be obtained for around £250 including a fixed disk. I have also seen offers of new mono single floppy models for £160. Shop around and look in the magazines.

One of the additional advantages of this combination is that the Pico Technology ADCs include additional software which is very useful to the enthusiastic ETI man.

Ref. 1. Earth Charge Recorder ETI, March and April 1992.

Ref. 2. see ETI RS232 Interface Dec. 1992 and Jan. 1993.

Ref. 3. ADC-16 from
Pico Technology Ltd.
Broadway House,
149-151 St. Neots Road,
Hardwick, Cambs. CB3 7QT.
Tel: 0954 211716.

Next Month

We will conclude this project by looking at how to implement the actual chart recorder function.

ETI Talkback

ELECTRONICS TODAY INTERNATIONAL

Dear ETI

I have noted your comments in February ETI regarding creativity and inventiveness. I have some ideas and would like to know what format you would like projects submitted in, with a view to having them published.

G.M.Horner, Pontefract.

This letter is representative of many that we have had recently. It seems that we at ETI are managing to stir up some response to our call for greater creativity and, more importantly you, our readers, are willing to write about their ideas.

So if you have an idea and have developed a project which you think other readers would be interested in, why not write an article for ETI?

Articles should be about 2000 words long, if longer then they should be split into two or more parts of about 2000 words each, and supplied as an ASCII text file on a MS-DOS disk (3.5in 720K, or 5.25 in). The format of the article should follow the pattern shown in other articles in this magazine, for example, those of Robert Penfold. All diagrams and PCB or Veroboard layouts should be provided in a clear form which can easily be redrawn by our artist. Any software used should be provided on MS-DOS disk. A working unit should also be available for examination be ETI editorial staff and for photography.

One plea though, please try and use components which everyone can easily get. Many a good project has not been built because readers could not get the components.

Don't be inhibited about writing, it is your ideas and your project that we are interested in, not your journalistic ability. So lets see some new authors, and don't forget that we pay for all published contributions!

Ed.

Dear ETI

As a Canadian reader I have just picked up my copy of ETI from the local news vendor. In the past, I have always appreciated the free PCBs etc. that often accompanied an issue. I was thus greatly disappointed to miss out on a free offering with the Layo1 PCB design and schematic diskettes. It appears that it was only made available to purchasers and subscribers in the UK. How can I get a copy, since it is a program I am particularly anxious to have?

Anthony. J. Smith, Manitoba, Canada.

Unfortunately, for a host of different reasons, not least those regarding distribution rights, etc., of a shareware programme, our many thousands of readers outside the UK missed out on getting a copy of Layo1. As did many UK readers who forgot to place an order with their newsagents only to find that ETI sold out very quickly. For readers who would like a copy of this programme we can, for a limited period supply the two disks at a price of £4.50 plus 60p P&P. Cheques should be made payable to ASP and addressed to
ETI Reader Services,
Argus House,
Boundary Way,
Hemel Hempstead,
Herts HP2 7ST.

Ed.

Dear ETI

Being an avid reader of ETI I wonder if you could help me out. Do you know of any electronics clubs in my area?

A.J.Wilkes. High Wycombe.

Mr Wilkes letter is typical of a great many similar enquiries that we receive. Indeed, to help readers like Mr Wilkes I put out an appeal last month for electronics clubs to contact me so that I can print a list of their locations, organiser names and contact numbers in the magazine. I would like to repeat that appeal. In the absence of a local club, readers might like to contact the British Amateur Electronics Club. They have a regular newsletter and maintain a library of data books for use by members. The BAEC can be contacted by writing to the Chairman,
Mr H.F. Howard,
41 Thingwall Park,
Fishponds, Bristol,
BS16 2AJ.

Ed.

Dear ETI

I would like to point out the dangers inherent in the design of the Programmable Stage Stroboscope (February ETI). The construction between those parts of the circuit accessible to the user, remoter run and remote fire, and those parts connected to the mains supply should, as designed, be of Class II safety construction. International safety standards specify minimum creepage distances and clearances for such construction between live parts and accessible parts as being 6mm. However, in the design of this circuit board, only 2mm has been provided.

Good design practice would not only be to provide the required 6mm distance but also to ensure that the isolated inputs are well separated from the other connections to the board, rather than being interspersed between them. This would then allow the wiring to be much more easily segregated. The live wiring and the isolated wiring should not only be segregated but secured such that then cannot move or touch any parts on the opposite side of the isolation barrier (the opto-isolators).

These opto isolators should also be of the correct type. A common misunderstanding is that the 'isolation voltage' often specified in catalogues is not the safe working voltage but is in fact the 'withstand' or 'dielectric strength' test voltage of the opto-isolators, which for Class II situations should be a minimum of 3000Vrms.

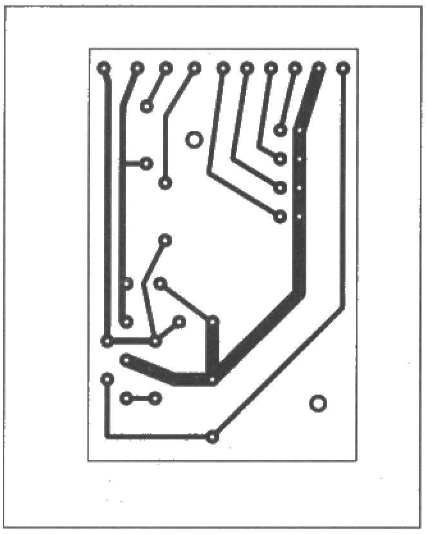
J. Pettifer, Epsom.

Mr Pettifer is absolutely correct in his observations about safety in circuits such as the Stroboscope. Readers who are building this project should take note, and if possible ensure that there is a 6mm clearance between the two sides of the isolation barrier. You may well not have any problem with the board layout we published, but when dealing with mains voltages it is always better to be safe than sorry!

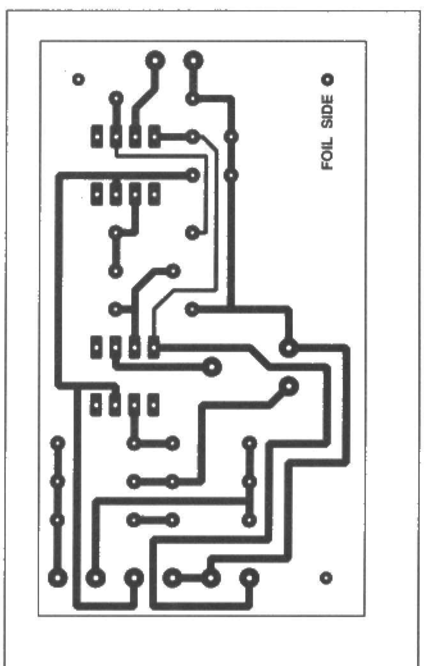
Ed.

ETI ELECTRONICS TODAY INTERNATIONAL

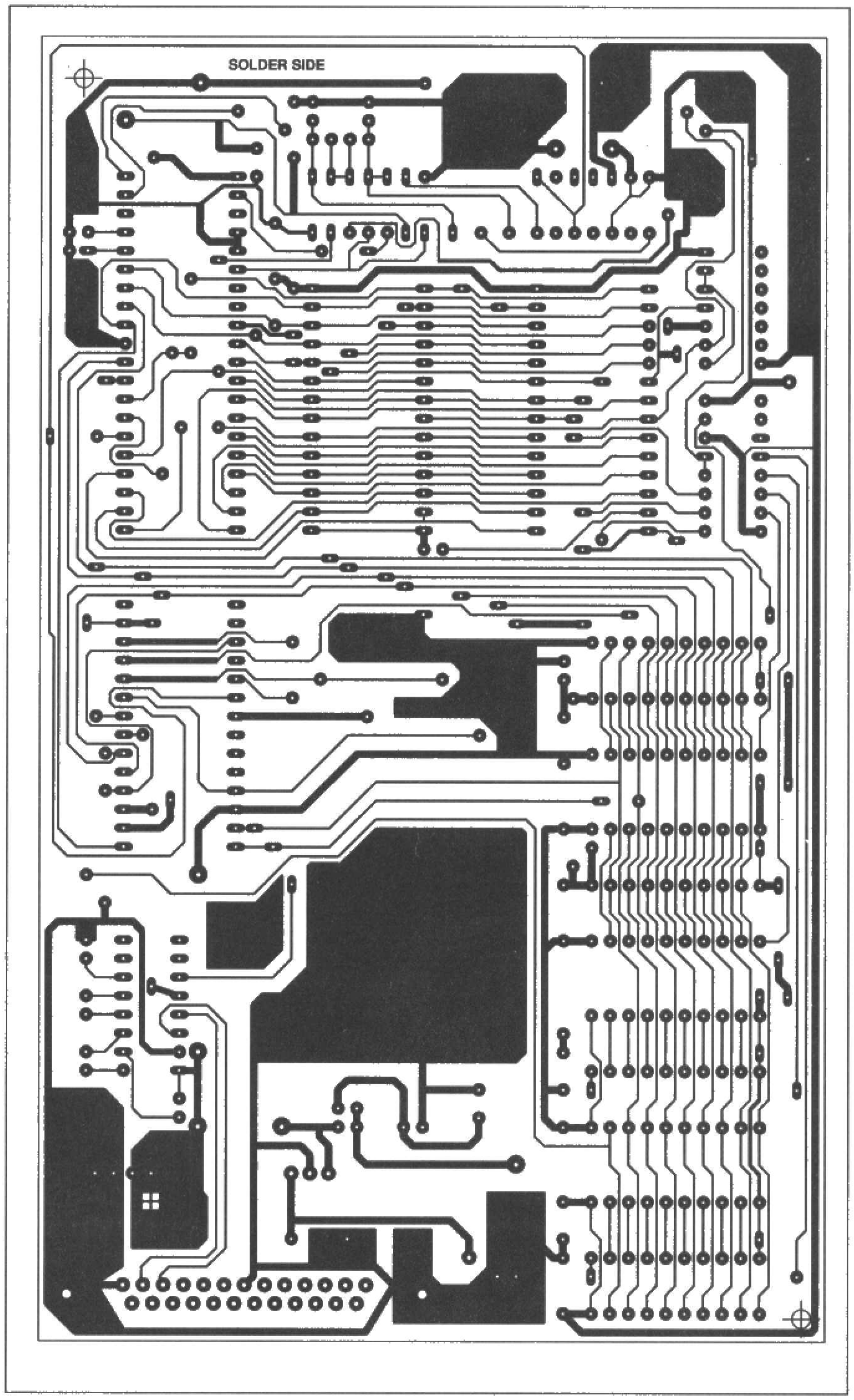
Foils for this issue



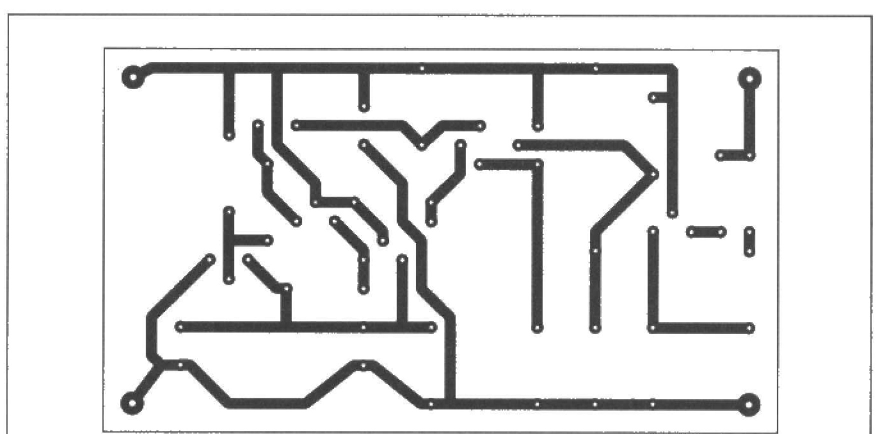
Low voltage PSU



Audio Millivoltmeter



Z80 Computer



Improved PSU

Open Forum

A couple of months ago ETI published a plea to encourage innovation and to help inventors. As I pointed out, Britain has a long history of inventiveness of which we can be truly proud. But despite such a tradition of inventiveness, we have, as a nation, a continuing inability to make use of this tradition, this talent.

The response which I received to this article was quite amazing. I have had phone calls and letters from many readers who have had personal experience in inventing something. All were frustrating experiences and all were unsuccessful in getting their inventions to the market place.

Now, I am not about to judge the commercial merits or otherwise of the proffered inventions, doubtless many would never become commercial products, even in the most favourable conditions. But one or two might well have made it. The unfortunate thing is that their developers were not given the opportunity to find out.

However, there were several common threads which ran through all these inventor's experiences. The first was the undoubted commitment and enthusiasm on the part of the inventor to his project (it is a funny thing, but all the respondents were male, is innovation primarily a masculine activity? If there are any female inventors I would like to hear about them.) Some must have spent thousands of man hours and considerable sums of money on their brainchild.

Another common thread was the lack of any help or information when it came to patenting the invention or in attempting to market it. The companies they approached were not interested, the local library was unable to help with information on patenting ideas, the banks were of no help in trying to find someone interested, civil servants in appropriate government departments were of even less help. Friends and relatives gave biased opinions and there was an aunt or two who offered to put up money to have it manufactured. But at no point did any of these inventors manage to find professional and impartial help.

The problem is, of course, partly the fault of the inventor, he quite naturally is obsessed with the idea, with the invention. To the inventor, questions of marketability, of ease of manufacturing, of production costs, of how the product would fit in the market place and what gives the product an edge over competing products, are subsidiary to the main goal of creating the product.

This obsession with the invention can prevent the inventor looking at his ideas in an impartial and objective manner. If he did, then perhaps he would be able to more easily recognise the merits and failings, from the point of view of a potential customer, retailer, or manufacturer. It is amongst retailers and manufacturers that the inventor will find his natural allies.

Both retailers and manufacturers need new products and a constant stream of them, to help fight the highly competitive battle that is today's business world. An inventor, who goes to such businesses with an idea which has been designed with marketing and manufacturing very much in mind from the beginning of the design process, will stand a good chance of being successful.

This means that the successful inventor has to be more than just a creator of new products. He has to have a solid background in current manufacturing technologies, in distribution, marketing, promotion, and costing. All thoroughly commercial areas of expertise, but without which the inventor will be faced with an infinitely harder task.

This brings me back to the ETI readers and their unsuccessful inventions. I think it is probably true to say that invention, like any creative activity, is a lonely task. You cannot rely on professional help, any more than an artist can rely upon an art critic to tell him how to improve his painting. You can only rely upon yourself and your own objectivity with respect to your creation.

The one thing that I sincerely hope is that these unsuccessful inventors will not give up inventing. I hope that they will persevere with new ideas, but that in the future they incorporate a more solid commercial element into their designs. Let us hope that this will make the difference between an invention's success and its failure.

Next month...

We continue the construction of Jim Spence's experimenters FORTH computer and take a look at the FORTH langauage, showing how it can be used for real time control systems. Dave Bradshaw builds an audio attenuator to accompany his Paleface Minor valve amplifier. For motorists, Terry Balbymie shows how to construct a handy little brake light monitor and Robert Penfold builds another useful piece of test equipment. Keith Garwell will be concluding his project to turn a PC into a virtual chart recorder.

There will also be the continuing series on robot vision and microprocessor fundamentals, as well as a look at the question of whatever happend to the R2D2 and the robot revolution.

ETI

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